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HISTORY OF ASTRONOMICAL SCIENCE IN KERALA

Thesis submitted to the University of Kerala for the Degree of Doctor of Philosophy in History

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CERTIFICATE

This is to certify that the thesis entitled **"History of Astronomical Science in Kerala"** submitted by *Mrs. Priya Kurian*, a full time Research Scholar in the Department of History, University of Kerala, for the Degree of Doctor of Philosophy in History, is a record of independent research work done by her during the period of study under my supervision. The thesis has not formed the basis for the award of any Degree, Diploma, Associateship and Fellowship or any other similar title.

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DECLARATION

I hereby declare that the thesis entitled **"History of Astronomical Science in Kerala"** is my original research work under the supervision and guidance of **Dr. B. Sobhanan**, Professor & Head, Department of History, University of Kerala, Trivandrum. This work has not been submitted earlier, in full or in part, for any Diploma or Degree in this or any other University.

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Date: 27.5.2009

PREFACE

The doctoral treatise "History of Astronomical Science in Kerala" attempts to trace the contributions of Kerala in the realm of astronomy both observational and computational through the ages. The history of astronomy in Kerala is a hitherto unexplored area. Among the scientific inventions and institutions, Kerala, commanded a pre-eminent status. But the historians and scholars paid little attention to unravel such secrets. Astronomy is one such area where the land of Kerala especially the princely state of Travancore made certain everlasting contributions. The genesis of Astronomical Science in Kerala can be traced from the ancient period. Kerala produced a number of astronomers during the medieval period and their works on astronomy, astrology and mathematics are valuable records. Thereafter the Europeans introduced the scientific knowledge of the west and brought contemporary science to India. It led to an intellectual awakening particularly from the nineteenth century. They began to construct observatories in different parts of the country. The Trivandrum Observatory was started in 1836 during the reign of His Highness Swathi Thirunal. Since then the observatory has contributed a lot to the development of astronomical science in Kerala till the present day.

The inventions and innovations of the eminent astronomers of Kerala during the ancient, medieval, modern periods have been analysed based on a multitude of primary sources such as Cover files, Confidential files, General files, Travancore Administrative Reports, Souvenirs etc. and secondary sources such as K.V.Sarma's *Contributions to the study of the Kerala School of Hindu Astronomy,* John Allan Brown's *Observations of Magnetic Declination made at the Trivandrum and Agustia Observatories in the Observatories of His Highness the Maharaja of Travancore in the years 1852 to 1869.* The collected sources were subjected to a thorough process of analytical operation.

Finally the scholar is able to establish that the astronomical investigations are a natural corollary to man's inquisitiveness and efforts to unravel the secrets of natural phenomena are as old as human civilization itself. Kerala kept the torch burning bright in this field and has contributed much to the growth and development of this science.

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CONTENTS

INTRODUCTION

Science is important to everyone as it plays a significant role in every society. It is concerned with the physical world and its phenomena entailing unbiased observations and systematic experiments. In general, science involves in a pursuit of knowledge covering general truths. Science began thousands of years before man learned to write. No one knows who first discovered fire, invented the wheel, developed the bow and arrow, or tried to explain the rising and setting of the sun. But all these events ranked as major advances in science. They were among man's first attempts to explain and control the things he saw around him. In general, mathematics was the first of the science to develop, followed by the physical sciences, the biological sciences and the social sciences.

The origin of the physical science can be traced in the observation of natural occurrences, such as the apparent movements of the heavenly bodies, and in the invention of rude implements, by the help of which men strove to increase the safety and comfort of their lives.[1] Ever since man learnt to walk upright, he has looked at the skies and wondered. His desire

[1] William Cecil Dampier, *A History of Science: And its Relations with Philosophy and Religion*, New Delhi, 1982, p. 1.

to understand the cosmic environment and put this understanding to practical use led to the development of astronomy.[2]

Astronomy, the "science of stars", is concerned with the physical universe. This science deals with planets and their satellites, including the earth and moon, with comets and meteors, with the sun, the stars and clusters of stars, with the interstellar gas and dust, with the system of the milky way and the other galaxies that lie beyond the milky way.[3] We live on a planet orbiting a star in an outer arm of the spiral milky way galaxy.[4]

Astronomy is the oldest scientific discipline mankind has known, which the eye of the sciences,[5] the most comprehensive of the sciences, astronomy is rightly called the Queen of all sciences.[6] It draws us from earthly occupations to the transcendentals of time and space, of speed and distance, of heat and light, of temperature and pressure, beyond human experience or imagination. It has been a subject that has attracted the attention of men from prehistoric times; and it is not easy to fix the date when the solar and lunar motions amid the fixed stars and the planetary motions first attracted the curiosity of the inhabitants of the earth.[7]

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2 G. Kuppuram & K. Kumudamani (ed.), *History of Science and Technology in India*, Vol. V, Delhi, 1990, p. 65.

3 Robert H. Baker, *Astronomy*, New Delhi, 1930, p. 1.

4 Stephen Hawking, *The Universe in a Nutshell*, London, 2001, p. 69.

5 Public Consultations, 1825, Tamilnadu Archives, Vol. 527, p. 881.

6 S. Kumaravelu, *Astronomy*, Sivakasi, 1986, p. 521.

7 O. R. Walkey & H. Subramania Iyer, *Concise General Astronomy*, Trivandrum, 1940, p. 1.

Modern astronomy tells us that the Universe is a collection of a large number of galaxies, each of which contains hundreds of billions of stars. The sun is an average star on the outskirts of the galaxy, called the Milky Way Galaxy. Around the sun go nine planets which, arranged in the order of increasing heliocentric distance, are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto. The last three are not visible to the unaided eye and were discovered using telescopes. In addition, the solar system contains very small planetary bodies, called the asteroids, mostly confined within the orbits of Jupiter and Mars. Finally, there are the comets, small 'ice balls' which develop spectacular tails when their orbits bring them close to the sun.

The ancient man's perception of the Universe was based on 'seeing is believing'. The Earth was assumed to be the centre of the Universe. Around it revolved the seven geocentric planets: Moon, Mercury, Venus, Sun, Mars, Jupiter and Saturn arranged in order of increasing geocentric distance. Beyond Saturn lay the unchanging fixed stars, stitched on the dark tapestry of the night sky. In the ancient Indian scheme of things, stars were observed not for their own sake but as a backdrop for the planetary motions. Such stars and star groups were called Naksatras.

The ancient planetary model was correct only in one detail: the Moon went around the Earth. Though physically wrong, the geocentric model could still provide correct orbital elements. The Earth's orbital period around the sun was attributed to the sun's virtual orbit around the Earth, so that the sun was said to take a year to go around the Earth. When the outer planets went around the sun, they went around the earth as well. Therefore, their geocentric and heliocentric periods were the same. In the case of the inner planets, Mercury and Venus, the geocentric theory replaced the planet with a mathematical artifact called Sigrocca. It was correctly assumed in ancient times that a longer orbital period implied greater geocentric distance for the planet. Thus the planets were correctly ordered according to their geocentric distance.[8]

Primitive cultures were well aware of the celestial world above them. They left pictorial evidence of their observations of stars, and the sun, moon and planets. Most of them associated deities or folk heroes with these celestial objects, and they all had some explanation of the creation of the universe. Because of their belief that the changes in the sky had an influence on human affairs, the orientation of their places of worship was usually aligned on the risings of specific stars or the direction of the rays of the sun on specific dates. These ancient structures were therefore both

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8 Rajesh Kochhar in A. Rahman (ed.), *History of Indian Science, Technology and Culture AD 1000- 1800*, New Delhi, p. 171.

astronomical and religious in purpose. Superstitious and ritualistic beliefs were intermingled with very good astronomy.[9]

It was not until the sixteenth and seventeenth centuries that the restrictions on scientific progress were broken down. The decline of the medieval political structure, the schisms within the church, and the early stirrings of the industrial revolution all had an effect. Scholars like Nicolaus, Copernicus, Galileo Galilei and Johannes Kepler found evidence of a new fact that could not be ignored: the sun was the centre of the solar system. The earth was merely one of the planets revolving about it. Human kind therefore was no longer at the centre of the universe. The universe was indeed vast, but it functioned by laws-natural laws-and these could be discovered through scientific processes.

Modern astronomy began about hundred and fifty years ago when the foundations of the current view of the universe were laid. Photography opened the door to exploration which previously had been impossible. Large telescopes, long photographic exposures, and other technological advances made the depths of space more accessible.

In the last fifty years, astronomy has undergone yet another radical change. More knowledge of the universe has been acquired in a short span

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9 Necia H. Apfel & J. Allen Hynek, *Architecture of the Universe*, California, 1972, pp. 1-2.

of time than in the whole previous history of astronomy. The very foundations of the science have been rocked with exciting discoveries, planetary explorations and challenging new theoretical models.[10]

The narrow strip of land, known as Kerala, lying along the south – west coast of the Indian peninsula, starting from near the southern tip, can be described as a land of treasures. Its spices and other gifts of nature attracted the trading community from several European countries, centuries back. The treasure of beauty and charm that nature has lavished on this landscape thrills the aesthetic sense of any visitor and makes him exclaim that this is really a tourists' paradise. These proud possessions of Kerala are well – known through out the world.

Another treasure has been lying hidden, for centuries, in this part of the country–a treasure consisting of works on Astronomy (including Mathematics), Medicine, Architecture etc. Only a few fragments of the 'treasure – trove' have so far been ferreted out. Even these reveal that this treasure is in no way less charming than the scenic beauty and is perhaps more valuable than the spices and other cash crops. When compared with similar findings from other parts of the world and belonging to the same

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10 *Ibid.*, pp. 5-11.

period, the state of knowledge indicated by some of these fragments is really astounding.

Here the study is confined to the mathematical and astronomical lore of Kerala. Among the academic activities of ancient and medieval Keralites, the study of Jyotiśh - śhāstra (the science of the celestial luminaries) was held in high esteem and hence it attracted the attention of a number of people, of whom some became ardent devotees to that branch of science. Anyone who glances even cursorily through the early history of Jyotiśh -śhāstra is sure to be struck by 'the elegant method of reckoning time' that was in vogue in Kerala from very early times. It may be said that in no other part of the world did there exist a method of time reckoning as scientific as the one in Kerala.

Jyotiśh – śhāstra comprises two parts: the theoretical part and the practical part–the latter being usually referred to as the predictional part. Phases of the moon, eclipses of the sun and moon, variations in the movements of 'planets' etc., are some of the topics which can be calculated in advance. These as well as descriptive details pertaining to the earth and other celestial bodies belong to the theoretical part. Reading of horoscopes, forecasting future events of persons, countries, reckoning of *muhurtams* (auspicious moments) etc., fall within the purview of the predictional part. Some people use the terms Astronomy and Astrology to denote the

theoretical part and predictional part respectively of Jyotiśh–śhāstra. Mathematics was an important and helpful tool to the study of Jyotiśh–śhāstra and was fostered as such. The result was that those mathematical topics like mensuration, properties of the circle, the sphere etc., needed in the study of Jyotiśh – śhāstra claimed the prime attention of the enthusiastic votaries of the muse of astronomy and gained phenomenal development.

Many great savants and preceptors flourished in this tract of the Indian peninsula at different periods of time and produced many authoritative treatises on Jyotiśh – śhāstra. *Deva – Keralam*, *Sukra – Keralam*, *Vararucci – Keralam* and *Keraleeya – Sutram* are a few among these works. *Sukra – Keralam* also known as *Brigu – Keralam*, *Keralarahasyam* and *Keraleeyam* is a work comprising ten chapters. *Vararuci - Keralam* is also referred to as *Jātakarahasyam* and *Keralanirnayam*. These treaties mainly deal with horoscopy and astrology – the predictional part of Jyotiśh – śhāstra, and contain some observational data and theoretical observations on celestial bodies.

A number of anecdotes of a mythical or legendary nature about these treatises and their authors have gained currency and the vast number of tales and folklores woven around them make it impossible to infer the

correct dates when these works were composed and when their authors lived.[11]

Mathematics and astronomy are two of the scientific disciplines to which significant contributions have been made, down the centuries, by Kerala scholars. The land of Kerala, a narrow strip of territory tucked away between the Western Ghats and the Arabian Sea, produced superb mathematicians from very early times. The fervor with which the sister science of astrology, in its different branches, was cultivated, had the beneficial effect of promoting the study of mathematics and astronomy, for the latter provided the basic framework for the practice of the former. The social structure which confined mainly, to certain sections of the community, the study of these disciplines and the freedom from political or religious upheavals which Kerala enjoyed helped the uninterrupted development, here, of these sciences.

As a result of all this, significant strides were made and a very large number of treatises came to be written, down to the nineteenth century, in these disciplines. However, only a fraction of these works have come down to us, the bulk having been lost on account of the ravages of time and the inclement climate of the land which had a highly detrimental effect on the palm leaf manuscripts on which these works had been inscribed. The highly

11 S. Parameswaran, "Kerala's contributions to Mathematics and Astronomy" in T. K. Ravindran (ed.), *Journal of Kerala Studies*, Trivandrum, 1980, pp. 142-143.

conservative outlook of the custodians of extant manuscripts of these technical texts, the local Malayalam language in which many of these works have been composed or commented upon and the rather obscure Malayalam script used for writing the manuscripts have all stood in the way of a proper study and interpretation of these works in terms of modern mathematics and thereby institute a proper evaluation there of.[12]

Astronomy being the main branch of Indian scientific tradition, received wider attention from the western adventurers in the eighteenth and nineteenth centuries. It became "a proof still more conspicuous of their (Indian) extraordinary progress in science". The advanced state of Indian astronomy had induced many western scholars to compile treatises on it. A set of Indian astronomical tables was first taken to Europe from Siam as early as in 1687 by De La Loubere, a French scholar. This set became an object of scientific curiosity in Europe. Two other sets of tables were sent from southern India by the Jesuit missionaries about the middle of the eighteenth century. Le Gentile, who visited India for the purpose of observing the transit of Venus in 1769, communicated an account of some tables of Hindu astronomy to the French Academy in 1773. The British astronomers contributed much to the growth of astronomical sciences in the eighteenth and nineteenth centuries.

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12 K. V. Sarma, *A History of the Kerala School of Hindu Astronomy*, Hoshiarpur, 1972, p. 1.

Methodology

The methodology used in this study is historical. The study is descriptive as it is factually grounded and elaborates on the history of Astronomy in Kerala till date, as well as it is easier to understand for anyone who reads on the subject. It is chronological as the events are arranged in their occurrence order and analytic as all the matters are analyzed carefully through primary and secondary sources and through observation in the Astronomical Observatory, Trivandrum.

Hypotheses

1. The achievements of some eminent astronomers of Kerala have been particularly remarkable as is evinced by the numerous contributions of various scholars in astronomy and astrology.

2. The members of the Kerala School were predominantly (Namboothiri) Brahmins.

3. Errors in observations at the Trivandrum Observatory are generally checked by the observations at Agustia, and vice versa.

4. The import of costly telescopes and clocks lagged behind due to financial difficulties and high customs duty.

5. The observatory has been functioning as a centre of education in astronomy.

Review of Sources

To study the history of Astronomical Science in Kerala the following sources have been consulted. Cover Files, Confidential Files, General Files, Travancore Administrative Reports, Annual Administrative Reports of the Madras Presidency, Public Despatches from England and Public Despatches to England, Manuscripts and Educational Records furnish a variety of primary data. Souvenirs such as the Centenary of His Highness the Maharaja's Observatory and the Silver Jubilee Souvenir of the Regional Meteorological Centre, *Journals of Kerala Studies* and the *Madras Journal of Literature and Science*, newspapers such as the *Hindu*, *Mathrubhumi* and the magazines such as *Frontline* and the *Observatory Magazines* provide corroborative data for reconstructing the historical development of astronomical science in Kerala.

Among the secondary sources, particular mention should be made of K.V.Sarma's *Contributions to the Study of the Kerala School of Hindu Astronomy,* O.P.Jaggi's *History of Science and Technology in India,* V.

Balakrishnan and R.Leela Devi's *Rig-Vedam,* Vallathol's *Rig Veda Samhita,* T.S.Kuppana Sastri and T.Chandrasekharan (ed.), *Mahabhaskariya of Bhaskaracarya,* K.Kunjunni Raja's *Astronomy and Mathematics in Kerala,* V.Narayanan Namboodiri's *Karanamrtam,* C.D.Maclean's *Manual of the Administration of the Madras Presidency,* John Allan Brown's *Observations of Magnetic Declination made at the Trivandrum and Agustia Observatories in the Observatories of His Highness the Maharaja of Travancore in the years 1852 to 1869,* S.Raimon (ed.), *Achieves Treasury* etc. These sources have been fully utilised for the study of Astronomical Science in Kerala.

Chapterisation

Besides an introduction, the first chapter provides information about the pre-scientific and scientific astronomy. The development of astronomical science in India could be studied under two heads, viz., pre-scientific astronomy and scientific astronomy. Chronologically, the pre-scientific period should be taken to commence from when the Vedic hymns began to be composed towards c. 4000 B.C. and to have lasted till A.D. 500 when, scientific astronomy emerged. The Vedic literature produced during this period is voluminous, though only stray passages therein are wholly astronomical in content. This literature includes the four Vedic Samhitās, viz., Rig Veda, Yajur Veda, Sāma Veda and Atharva Veda, the Brāhmanas,

the Āranyakas, Upanisads; and the six Vedāngas. The two epics of India, viz., the Mahābhārata and the Rāmāyana contain several useful references.

The Jaina texts also contain astronomical material. Last to come in this period is the Siddhantas. Scientific astronomy is said to have commenced when the fundamentals of the science had been established and strict rules and procedures of computation had been formalized. The system could then grow on a rational basis. It is divided into two sub-periods, of which the earlier one only has historical importance. This may be considered to coincide closely with the period of the Gupta dynasty (A.D. 320-650) and it embraces the most celebrated of the Hindu astronomers- Āryabhatta, Vararuci, Varāhamihira, Brahmagupta and Bhaskara I. The second sub-period, which extends from about A.D. 700 to the present day, is of sub-ordinate interest altogether in India. Bhaskara II is the only conspicuous figure and his importance has been some what exaggerated.

The second chapter describes about the development of astronomical science in Kerala. Though with Bhaskara II ended the great era of mathematics in North India, Kerala continued to make its mark in the field. What is most striking is that when mathematical studies else where in India languished with the end of the epoch of Bhaskara, Kerala kept the tourch burning bright in this field of knowledge. Apart from elaborating and improving upon the Aryābhattiya School of astronomy, Kerala evolved its

own schools of astronomy like the *Parahita* and *Drigganitha* Systems which had their own distinct advantages. Kerala produced a number of astronomers during the medieval period and their works on astronomy, astrology and mathematics are valuable records. Indeed the achievements of some eminent astronomers of Kerala such as Vararuci, Sankaranārāyana, Talakkulathu Govinda Bhattatiri, Sangamagrāma Mādhava, Parameswaran etc., have been particularly remarkable.

The third chapter deals with The Trivandrum Observatory. The astronomical science had an isolated life of its own. But with colonial intervention it took a different dimension. Astronomy being the main branch of Indian scientific tradition received wider attention from the western adventurers in the eighteenth and nineteenth centuries. The motive behind the British to develop astronomical science was their commercial interest and political ambition and also 'for promoting the knowledge of Astronomy, Geography and Navigation in India. For this purpose they began to construct observatories in different parts of the country. The first astronomical observatory in India was established in Madras during 1792 by the British East India Company. It was the first modern public observatory outside Europe. It was used as India's first modern research institute. An observatory was started at Trivandrum in 1836 during the reign of His Highness Swathi Thirunal. Caldecott was appointed the first

director of the observatory in addition to his being the court astronomer. The chapter consists of choosing a site for the erection of the observatory, construction of the observatory building, the first astronomical instruments and it concludes with the death of Caldecott in 1849.

The fourth chapter is about John Allan Brown and the Agustia Observatory. Caldecott was succeeded by John Allan Brown in 1852 who fitted up the institution for magnetic and meteorological observations. Brown was primarily interested in meteorology and particularly in terrestrial magnetism. John Allan Brown examined the laws of terrestrial magnetism and the variation of meteorological elements as influenced by height in the atmosphere. This, he thought, was possible only by simultaneous observations at two stations differing in height, as he thought that observations should not be limited to a single station, but that the standard observatory should serve not merely for the determination of the laws and physical constants at one point, but also for the comparison and co – ordination of the laws depending on differences of height, of latitude and of longitude. Therefore he later on devoted himself solely to magnetic observation for which he set up a special observatory at Agustia Malley, within three years of his joining the Trivandrum Observatory. The chapter deals with the observations made at the Agustia-Malley and Trivandrum, closing of the observatory and the retirement of Brown.

The fifth chapter describes the later development of astronomical science in Kerala till date. After the departure of Brown in 1869 there was a period of lull till Mitchell offered his services to the Government as honorary director of the institution in 1892. Mitchell introduced a scheme of rainfall measurements in the state with a specially designed rain gauge. He engaged the staff of the observatory in the compilation of a table for the reduction of observations on vapour pressures and the completion of the humidity table. Cloud studies were also began during his period. The observations thus collected were telegraphed to the Meteorological Department of the Government of India and were published weekly in the Government Gazette. On 27 February 1928, the meteorological and the astronomical branches of the observatory were made independent of each other and were placed under the respective control of the Government meteorologist and the Government astronomer. Subramania Iyer was appointed as the Government astronomer. The activities of the astronomical department were the standardization of local time by star observations with the transit circle, the calculation of astronomical data for the Government almanac and directory and in helping visitors at star gazing with the help of the equatorial telescope. On August 17, 1939 the observatory was transferred to the control of the University. From January 18, 1960 the administrative control of the observatory was transferred to the Revenue Board, Trivandrum. Due to its lack of activities, the Government of Kerala

decided to transfer the observatory back to the control of the University on January 1, 1976 and it now functions as an institution under the department of physics, University of Kerala. The chapter also deals with the various activities of the observatory till the present years.

Conclusion contains a critical assessment of the development and working of the Trivandrum Observatory and a brief account of the astronomical organizations in Kerala and its contribution to the growing knowledge in astronomical science.

CHAPTER – I

HISTORICAL BACKGROUND OF ASTRONOMY

The antiquity of astronomical studies in the Indian subcontinent can be traced from the pre-vedic periods. Inscriptions of astronomical phenomena are deciphered from the two Mohenjadaro seals dating at least 2500 B.C.[1] An attempt by Finnish philologists to read the Indus script using a computer method seems to indicate that the *nakshatras* are of Harappan origin, as also are the later Dravidian names of the five planets related to their colours (e.g. Mars, the 'red star'). Should this be substantiated, it would locate the origin of the *nakshatras*, traditionally associated with the Hindus, within the earlier Indus Valley Culture.[2]

The science of astronomy was known to the Sangam people and the twin epics mention astronomical details. In Puram, 221 the position of stars and planets is given for the fall of a meteor in the reign of the Chera dynasty of the elephant look. In Purananūru, ode, 229 Kūdalūrkilar describes elaborately the point in the sky where he saw a shooting star.[3]

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1 T. E. Girish, "Hindu Astronomy and Kerala Culture", in S. Murali (ed.), *South Indian Studies*, Delhi, 1998, p.145.

2 H.J.J. Winter, "Science", in A. L. Basham (ed.), *A Cultural History of India*, Oxford, 1975, p. 161.

3 Tamilzhannal & Annamalai (ed.), *Purananūru*, Kūdalūrkilar, Puram, Ode, 229, Verse 10-14, p. 368.

In Agam, 313 the setting of the sun is described with reference to the moon being swallowed up by the serpent and so on.[4]

Vedic Aryans in fact deified the sun, stars and comets. Astronomy was then interwoven with astrology and since ancient times Indians have involved the planets (called *Grahas*) with the determination of human fortunes. The planets *Shani*, i.e. Saturn and *Mangal* i.e. Mars were considered inauspicious.[5]

Astronomy, Astrology and Mathematics formed the three main divisions of *Jyothisham*. The movement of the stars and planets were studied from very early period and their influence on the weather; the plant life and human life were also recognized and studied. This resulted in the development of Astronomy and Astrology.[6] Calculation of the time was part of the sacred ritual with the Vedic Aryans. Religious sacrifices that they performed were of different types. While some of them were performed at a particular time of the day, the others were performed at full or new moon or when the days and nights were of equal length, and occasionally a sacrificial ritual lasted even for a year or more. Not only that, the sacrificial altar had to face a particular direction also, as for example,

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4 M. Arokiaswami, *The Classical Age of the Tamils*, Madras, 1967, p.113.
5 www.sudhanshu.com/histroy.html
6 T. K. Ramachandra Iyer, *A Short History of Sanskrit Literature*, Palghat, 1995, p.184.

the east. So we see that the Aryans had to have a fairly broad based idea of the time and the direction, from very early times.[7]

The Vedic literature produced during this period is voluminous, though only stray passages therein are wholly astronomical in content. This literature includes, primarily, the four Vedic Samhitās, viz., Rig Veda, Yajur Veda, Sāma Veda and Atharva Veda, in their several recessions. The extensive elucidatory literature thereon, called the Brāhmanas, and the supplementary texts thereto, called Āranyakas; the philosophic expositions called Upanisads; and the six Vedāngas. Two of these six Vedāngas, Viz., Jyothisha and Kalpa, the latter in its last section called Sulba, are of particular importance in the study of the growth of astronomy in India. The former, viz., *Vedānga – Jyothisha*, being short texts attached to the Rig-Veda, Yajur Veda and the Atharva Veda sets out certain definite aspects of Vedic astronomy, while the latter, viz., the Sulbasūtras, being menstruation manuals for the construction of different types of fire altars, such as Baudhayāna, Āpastamba, Kātyāyana, Mānava, Maitrāyaniya, Vārāha and Vādhūla, codify the practical side by vedic astronomy. The two epics of India, viz, the Mahābhārata and the Rāmāyana, which too, belong to the pre-scientific age of Indian astronomy, contain several useful references. So also the earlier purāna texts. The Jainas had fervour for mathematics and in

[7] O. P. Jaggi, *History of Science and Technology in India*, Vol.2, Delhi, 1969, p. 99

some of their canonical texts is to be found a section named Ganitānuyoga 'system of calculation'. The Jaina texts also contain astronomical material. Last to come in this period are the five systems of astronomy viz., the Paitāmaha–Siddhānta, Vāsistha–Siddhānta, Saura-Siddhānta, Romaka – Siddhānta and Pauliśa-Siddhānta, whose original texts are not available now, but whose tenets have been set out by Varāhamihira in his *Pāncha-Siddhāntikā* (A.D. 505).

Early texts:

"Like the crests on the heads of peacocks, like the gems on the hoods of the cobras, *jyothisha* (Astronomy) is at the top of the *vedānga sastras* – the auxiliary branches of Vedic knowledge".

Vedānga Jyothisha, 4

The above verse shows the singular importance given to astronomy (and mathematics) over the other branches of knowledge in the vedic times. In the vedic literature, *Jyothisha* is one of the six auxiliaries (*shadangas*) of the vedic corpus of knowledge. The six Vedāngas are

i. Siksa (phonetics)
ii. Vyākarana (grammar)
iii. Chandas (metrics)
iv. Nirukta (etymology)

v. Jyothisha (astronomy) and

vi. Kalpa (rituals)

It is important to note that although in modern parlance the word Jyothisha is used to mean predictive astrology, in the earlier literature Jyothisha included all aspects of astronomy. Mathematics was regarded as a part of Jyothisha. *Vedānga Jyothisha* is the earliest Indian astronomical text available.[8]

In the early works direct references to the subject of astronomy are very few. In the Yajur Veda the *nakshatradarsa* (star-gazer or astrologer)[9] is mentioned as one who would bring 'insight if offered up as a sacrifice; and in the same list of human victims the *ganaka* (calculator or astrologer)[10] is said to bring 'power' to the sacrificer. The Chāndogya Upanishad gives lists of subjects known to Nārada and these lists include *nakshatra vidyā* (astronomy) and *rāsi* (quantity or number).[11]

The Rig Veda:

In Rig Veda the sun is the source of light, out-strips all in speed,[12] measures day and night,[13] drives away the stars and night like thieves.[14]

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8 S. Balachandra Rao, *Indian Astronomy – An Introduction*, Hyderabad, 2000, pp. 1-2.

9 Ralph T. H. Griffith, *The Yajur Veda Samhitā*, Delhi, 1990, XXX, 10, p.452.

10 *Ibid.,* XXX, 20, p. 455.

11 Swami Swahananda, *The Chāndogya Upanisad*, Madras, 1975, VII, 1^2, p.480-481, 1^4, p.485, 2^1, p.487, 7^1, p.504.

12 V. Balakrishnan and R. Leela Devi, *Rig Vedam* (Mal.), I, $50^{4,5}$, Vol.I, Trivandrum 1976, p.138.

13 *Ibid.,* I, 50^7, p.138.

14 *Ibid.,* I, 50^3.

The sun's chariot has seven[15] horses generally but occasionally five, or six, or a thousand.[16] Occasionally the sun was overspread with darkness by *Svarbhānu,* which was dissipated by Atri and by prayer.[17]

The moon appears to order the seasons and is continually born again. The sun and moon 'ascend alternate', and move in close succession'[18] but the moon plays a subordinate part throughout, although *Soma* (afterwards a Moon–God) is, from a non-astronomical point of view, of supreme importance.

The year has twelve months and 360 days, and is divided into four quarters of 90 days each.[19] There is no definite reference to a five year cycle,[20] nor any explicit reference to an intercalary month.[21] The account of the Ribhus reposing for twelve days[22] has been supposed to imply a lunar year of 354 days with the 12 additional days making 366 in all.

There are doubts about the mentioning of some planets in Rig Veda. A great deal of ingenuity has been exercised in trying to discover references

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15 *Ibid.,*I, 50^{8}, p.139, I, 164^{2}, p. 397, VI, 44^{24} , p. 553 etc.

16 O.M.C. Narayanan Namboodiripad, *Rig Veda Bhasya –Bhasyam* (Mal.), V, 62^{1}, Vol.4, Kottayam,1982, p.244.

17 *Ibid.*, V, $40^{5\text{-}8}$, Vol.4, pp. 111-113, IV, 28^{2}, Vol.3, p.480.

18 Vallathol, *Rig Veda Samhita* (Mal.), X, 85^{18}, Vol. IV, Trichur, 1958, p. 366.

19 O.M.C. Narayanan Namboodiripad, *op. cit.,* Vol.2, I, 164^{11}, p.399, I, 164^{48}, p.408, I, 155^{6}, p.378.

20 *Ibid.,* But see, III, Vol.2 55^{18}, p. 267.

21 V. Balakrishnan and R. Leela Devi, *op. cit.*, I, 25^{8}, p. 272 has been supposed to imply an intercalary month

22 O.M.C. Narayanan Namboodiripad, *op. cit.*, IV, 33^{7}, Vol.3, p. 512.

that imply the planets or a knowledge of them but without any assured success. Brihaspati was later on the name for Jupiter and it is possible that in the Rig Veda the planet is meant by Brihaspati[23] but this is only conjecture. The cloud-born Vena[24] has been equated with Venus but without general acceptance.

Of constellations there are few definitely mentioned: *Aghās* and *Arjunī*[25] are usually identified with the adjacent asterisms *Maghā* and *Phalgunī; Tishya* may be a special star.[26]

The Yajur-Veda:

The Yajur Veda (Taittirīya Samhitā) gives a list of twenty–seven asterisms or *nakshatras*, commencing with Kṛittikā.[27] It also states definitely that "the full moon in Phalguni is the beginning of the year".[28] Thus the Taittirīya Samhitā gives the two most important contributions to vedic astronomy. Nakshatra lists are also given in the Maitrayani and Kathaka Samhitās and in the Atharva Veda.

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23 *Ibid.*, IV, 50^{4}, p. 578.
24 Vallathol, *op.cit.*, X, 123^{2}, p. 468.
25 O.M.C. Narayanan Namboodiripad, *op.cit.*, X, 85^{13}, Vol.7, p. 366.
26 Vallathol, *op. cit.*, V, 54^{13}, p.206, X, 64^{8}, p. 322.
27 Arthur Berriedale Keith, *The Veda of the Black Yajus School entitled Taittirīya Samhita Part 2: Kandas IV-VII*, IV, 4^{10}, Delhi, 1914, p.349.
28 *Ibid.*,VII, 4^{8}, p. 607.

The Atharva Veda:

The Atharva Veda refers explicitly to a thirteenth month of 30 days,[29] which possibly implies a five year cycle of 5x360 +30=1830 days, such as is exhibited in the *Vedanga Jyothisha* etc. The names of the year as given in several of the Samhitās are of no astronomical value.[30] The Atharva Veda also mentions eclipses on several occasions[31] and introduces Rahu,[32] the demon of eclipses; Soma and Rudra remove the eclipse.[33] The *nakshatra* list of the Atharva Veda consists of 28 asterisms and is apparently of an astrological character.[34]

Subsidiary texts:

The Brāhmanas add very little of astronomical value. A Brāhmana or religious manual and a Sutra or collection of rules are attached to each Veda; and that the Brāhmana is further divided into three rather vague orders of which the Vedanta or Upanishad is chiefly concerned with theosophical speculations.[35] The Vedāngas are subsidiary works of later date dealing with the several branches of secular knowledge. There are definite references to a thirteenth month of thirty-five days or thirty-six

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29 William Dwight Whitney, *Atharva Veda Samhita,* XII, 3^8, Vol. 2, Delhi, 1987, p. 729, V, 6^4, Vol.1, p. 174.
30 *Ibid.*, IX, 7^3, Vol. 2, Delhi, 1962, p. 547.
31 *Ibid.,* III, 2^2, Vol.1, p. 38.
32 *Ibid.*, XIII, 4^{25}, Vol.2, p. 734.
33 *Ibid.,* XIII, 4^{26}, p 734 and xix,9^{10}, p. 914.
34 *Ibid.*, XIII, 4^{28}, p. 734.
35 G. R. Kay, *Hindu Astronomy,* New Delhi, 1981, p. 8.

days. The Upanishads add nothing of special interest except, perhaps, a reference to the 'fixed' (*dhruva*) pole star. The *nakshatras* appear to occupy equal spaces of $13^{1/3}$ degrees and the year appears to be divided at the beginning of *Māgha*[36] or the end of *Asleshā*[37] The terms *ketu* and *graha* are employed but not with any definite astronomical denotation.[38]

Vedānga Jyothisha:

Vedānga Jyothisha is the earliest Indian astronomical text available. The *Vedānga Jyothisha* was mainly used to fix suitable times for performing different kinds of sacrifices. The text is found in two rescensions- Rig Veda Jyothisha and Yajur Veda Jyothisha. Though the contents of both the rescensions are the same, they differ in the number of verses. While the Rig Vedic versions contain only 36 verses, the Yajur Vedic version contains 44 verses. This difference in the number of verses is perhaps due to the addition of explanatory verses by the Adhvaryu priests by whom it was used.

In one of the verses, it says, "I shall write on the lore of time, as enunciated by sage Lagadha".[39] Therefore, the authorship of *Vedānga Jyothisha* is attributed to Lagadha. Hence Lagadha is sometimes called the father of Indian astronomy.[40]

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36 Magha is the tenth lunar asterism, sometimes regarded as the wife of the moon in Hindu mythology.

37 Aslesha is the seventh lunar asterism.

38 G. R. Kay, *op. cit.*, p. 13.

39 S. Balachandra Rao, *op.cit.*, pp. 2-3.

40 N. Gopalakrishnan, *Indian Scientific Heritage*, Thiruvananthapuram, p. 9.

The *Vedānga Jyothisha* belongs to the last part of the Vedic age. The text can be considered as a record of the fundamentals of astronomy necessary for the day-to-day life of the people of those times. The *Vedanga Jyothisha* is the culmination of the knowledge developed and accumulated over thousands of years of the Vedic period up to 1400 B.C.

Even as early as the time of the mandalas of the Rig Veda, the Vedic people were conversant with the knowledge required for their religious activities, like the times (and periodicity) of the full and the new moons, the last disappearance of the moon and its first appearance, etc. This type of information was necessary for monthly rites like *darsapurnamasa* and seasonal rites like *cāturmāsya*.[41]

The Nakshatra System consisting of 27 *nakshatras* (or 28 including Abhijit)[42] was evolved long ago and was used to indicate days. It is pointed out that *Agrahāyana*, an old name for the *Mrigasira nakshatra*, meaning "beginning of the year" suggests that the sun used to be in that asterism at the time of the vernal equinox. This corresponds to the period around 4000 B.C.

During the Yajur Veda period, it was known that the solar year has 365 days and a fraction more. In the Taittirīya Samhitā, it is mentioned that

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41 S. Balachandra Rao, *op. cit.*, p. 3.
42 Abhijit is the twenty seventh lunar mansion.

the extra eleven days over the twelve lunar months, totaling 354 days, complete the six *ṛtus* by the performance of the *ekadasa–ratra*, i.e., eleven-night's sacrifice. Again, the same Samhitā says that five days more were required over and above the sayana year of 360 days to complete the seasons, adding specifically that: " four days are too short and six days too long".

The Vedic astronomers evolved a system of five year's *Yuga*. The names of the five years of a *Yuga* are:

i. Samvatsara

ii. Parivatsara

iii. Idavatsara

iv. Anuvatsara, and

v. Idvatsara.

This period of a *Yuga* (of five years) was used to calculate time.

In the Yajur Veda, a year comprising twelve solar months and six *ṛtus* (seasons) was recognized. The grouping of the six *ṛtus* and the twelve months, in the Vedic nomenclature, is as follows:

Seasons	Months
1 Vasaṇta ṛtu	Madhu and Mādhava
2 Grīsma ṛtu	Śukura and Śuci
3 Varṣa ṛtu	Nabhasd and Nabhasya
4 Śarad ṛtu	Isha and Urja
5 Hemanta ṛtu	Saha and Sahasya
6 Śisira ṛtu	Tapa and Tapasya

The sacrificial year commenced with Vasanta *ṛtu*. The Vedic astronomers had also noted that the shortest day was at the winter solstice when the seasonal year Śisira began with *uttarayana*, and rose to the maximum at the summer solstice.

In the *Vedānga Jyothisha* a *Yuga* of 5 solar years, consists of 67 lunar sidereal[43] cylces,1830 days,1835 sidereal days,62 synodic months,[44] 1860 tithis,[45] 135 solar *nakshatras*, 1809 lunar *nakshatras* and 1768 risings of the moon. It also mentions that there are 10 *ayanas* and *visuvas* and 30 *ṛtus* in a *Yuga.*[46]

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43 A celestial meridian is an imaginary line in the celestial sphere, fixed relative to the stars. The moon is observed to cross any particular meridian every 27. 32166 days. This is the sidereal period or sidereal month.

44 A synodic month is the interval between successive conjunctions of the moon and sun i.e from any new (or full) moon to the consecutive new (or full) moon. The synodic month is also known as lunar month.

45 One tithi is one lunar day. One tithi is the interval of time during which the moon gains 12 degree of longitude over the sun.

46 S. Balachandra Rao, *op. cit.*, p.4.

The practical way of measuring time is mentioned as the time taken by a specified quantity of water to flow through the opening of a specified *clepsydra* (water –clock), as one *nādikā,* i.e., $\frac{1}{60}^{th}$ part of day. The *Vedānga Jyothisha* also has a useful classification of those times like.

i. The solstices

ii. Increase and decrease of the durations of days and nights in the *ayanas.*

iii. The solstitial *tithis*

iv. The seasons

v. Omission of *tithis*

vi. Table of *parvas*

vii. *Yoga's* (which developed later as one of the five limbs of a full fledged pancanga)

viii. Finding the *parva nakshatras* and the *parva tithis.*

ix. The *visuvas* (equinoxes)

x. The solar and other types of years.

xi. The revolutions of the sun and the moon (as seen from the earth).

xii. The times of the sun's and the moon's transit through a *nakshatra.*

xiii. The *adhikamasa* (inter calary month)

xiv. The measures of the longest day and the shortest night etc.

The *Vedānga Jyothisha* mentions that the durations of the longest and the shortest days on the two solstices are thirty six and twenty four *ghaṭikā* (*nādikās*) which corresponds to 14 hours, 24 minutes and 9 hours, 36 minutes respectively. This means the *dinardha,* i.e. the length of half day, comes to be 7h 12m and 4h 48m respectively, which differs from 6h by 1h 12m. This is called the ascensional difference. It is calculated that around 1400 B.C, the sun's maximum declination used to be about $23^{\circ}53'$. However, our ancient Indian astronomers took it as 24°. Now, the latitude of a place can be found using the formula:

Sin (ascensional difference) = $\tan\phi \tan\delta$ where δ is the declination of the sun. The correction due to the ascensional difference in this case is 1h 12m, i.e., in angular measure, 1h 12m X $15^{\circ} = 18^{\circ}$. By using the above formula, we get the latitude of the place as $\phi = 35^{\circ}$ approximately. Therefore, the place of composition of the *Vedānga Jyothisha* appears to be in some region around the northern latitude of 35 degrees.[47]

Rāmāyana and Mahābhārata:

The Mahābhārata, Rāmāyana and the Purānas occupy a peculiar position in the history of Hindu astronomy. They embody certain ancient astronomical traditions. They contain a good deal that does not obviously

47 *Ibid.*, p. 5.

appertain to the earlier period. On other than astronomical grounds the later limit of portions of the *Mahābhārata* has been fixed at about A. D. 400 and the texts of the Purānas generally contain unambiguous evidence that they are at least as late as that date. Citations from the epics and the pseudo historic Purānas must therefore be employed with circumspection.[48] The *Mahābhārata*, the longest epic poem contains interesting material of a quasi-astronomical nature.[49] The five year cycle is mentioned and it is stated that there would be an excess of two months in five years, and of five months six days in thirteen years.[50] The Kṛita Age is also mentioned without specifying the length of the period, and it is said that it will come again when the sun, moon, the *nakshatra* Tishya (=Pushya) and Jupiter meet in one sign.[51] The *nakshatras* are generally 27 in number[52] but 28 seem occasionally to be implied.[53] The month begins with the bright fortnight (new moon to full moon) and a half month contains 14, 15 or 16 days. An eclipse occurring on the13[th] day is mentioned.[54] The planets are mentioned by name in the following order: "Venus, Jupiter, Mercury, Mars, Saturn, Rahu and the other planets".[55] The stars though "so small in consequence of their distance, are large".[56]

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48 G. R. Kay, *op. cit*., p. 8.
49 *Ibid.*, p. 14.
50 R. N. Dandekar (ed.), *The Mahabharata*, VI, 52^{3}, Vol.2, Poona, 1971, p. 1210.
51 *Ibid.*, III, 190^{90}, Vol. 1, p. 656. Pushya is supposed, more or less, to coincide with cancer. See also the Ramayana, I, 60.
52 *Ibid.*, I, 66^{16}, Vol. 1, p. 98.
53 *Ibid.*, V, 110^{15}, Vol.2, p. 1031.
54 *Ibid.*, VI, 3^{32}, Vol.2, p. 1132.
55 *Ibid.*, II, 11^{37}, Vol. 1, p. 305.
56 *Ibid.*, III, 42^{24}, Vol. 1, p. 446.

The Rāmāyana:

The *Rāmāyana* mentions a number of *nakshatras* and generally with reference to the position of the moon[57] and in one case Pushya appears to be equated with Mīna (Pisces). Of particular constellations the Great Bear and Triśanku occur.[58] The planets Mars, Mercury, Jupiter and Venus are definitely mentioned.[59] One whole canto is devoted to the glory of the sun.[60] Rahu, as the enemy and devourer of the moon, is mentioned on several occasions,[61] but Ketu does not appear to occur. Meru is stated to be the best of mountains and is generally coupled with some other mountain range, e.g., Vindhya, Himavān.[62]

The Purānas:

The chief characteristic of the Purānas is perhaps connected with cosmological notions. The following is condensed from the Vishnu Purāna. The seven great islands are surrounded by seven great seas. Jambū-dvīpa is the centre of all these; and in the centre of this is the golden mountain Meru. The height of Meru is 84,000 yojanas and its depth below 16,000. Its diameter at the summit is 32,000 and at its base 16,000; so that this

57 Ralph, T. H.Griffith, *The Ramayana of Valmiki,* Canto 1, Varanasi, 1977, Vol. XXIX, Book I, pp. 3-4.
58 *Ibid.,* Canto XIX, Book.1, p. 32.
59 *Ibid.,* Canto XIX, Book.1, p. 31.
60 *Ibid.,* Canto CVI, Book. 6, p. 489.
61 *Ibid.,* Canto IV, Book. 2, p. 93.
62 *Ibid.,* Canto, 1, Book. 1, p. 4.

mountain is like the seed cup of the lotus of the earth....The orbit of the sun is 100,000 yojanas from the earth and that of the moon an equal distance from the sun. At an equal distance above the moon is the sphere of the *nakshatras*. Mercury is 200,000 yojanas beyond, Venus 200,000 further still, Mars 200,000, Jupiter 200,000 and Saturn 250,000 yojanas beyond Jupiter. The sphere of the seven Rishis is 100,000 yojanas beyond and at the same distance above is Dhruva, the pivot or axis of the whole planetary circle.[63] One of the most extraordinary astronomical theories that occur in Hindu literature is connected with the seven Rishis, which are generally identified with the Great Bear. The principal authorities are the Pauranic texts and Varahamihira.[64] Beyond Dhruva are the four heavens....on Dhruva rest the seven great planets, and on them depend the clouds. As Dhruva revolves it causes the moon, sun and stars to turn round also, and the *nakshatras* follow in its circular path: for all the heavenly bodies are, infact, bound to the polar star by aerial cords....

This order was not strictly followed by the later astronomers who placed the sun in its correct relative position and the *nakshatras* or stars beyond the furthest planet, and omit the seven Rishis and Dhruva. Besides the five planets, Rahu and Ketu are mentioned and each of the seven has a chariot drawn by eight horses.[65]

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[63] H. H. Wilson, *The Vishnu Purana*, II. 5, p.136, II. 13, Book: 2, Calcutta, 1961, p.139.
[64] G. R. Kay, *op. cit.*, p. 16.
[65] H. H. Wilson, *op. cit.*, VIII, 2, Book. 2, pp. 178-179.

It is implied that the winter solstice takes place at the beginning of the month Tapas (Māgha), and an equinoxes, apparently, supposed to take place in Kṛittikā or Visākhā.[66] There is also a reference to the recurrence of the Kṛitā age similar to that given in the epic.

The Jatakas:

Buddhist texts are often severe in their condemnation of star-gazing, astrology and such practices as the fore telling of eclipses; but the Jatakas contain fairly numerous references to astronomical matters.[67] In number 20 the Kappa or era, with its four era miracles is mentioned, the first of these miracles being 'the sign of the hare in the moon, which will last the whole era.'[68] In number 48 a charm is to be repeated at a certain conjunction of the planets, and the magician is made to say "It will be a year before the requisite conjunction of the planets takes place again."[69] Similar references to conjunctions of the planets are made in numbers 474,481 and 522. In number 481 the goblin on releasing the prince says: "Go forth from my hand, even as the moon from the jaws of Rāhu;" and such references to the demon of eclipses recur pretty often.[70]

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66 *Ibid.,* VIII, 17, 18, p. 185.
67 G. R. Kay, *op. cit.,* p. 14.
68 E. B. Cowell (ed.), *The Jatakas*, Delhi, 1895, Vol. 1, p. 56.
69 *Ibid.*, p. 121.
70 G. R. Kay, *op.cit.*, p. 14.

Jaina Astronomy: The Sūryaprajnapti

The principal source of information about the Jaina astronomical text is the Sūryaprajnapti. The Sūryaprajnapti is, from the astronomical point of view, of much the same type as the *Vedānga Jyothisha* but, possibly, it is of a later period. Popularly the most marked feature of the system set forth in the Sūryaprajnapti is the some what strange cosmography that appears to have been peculiar to Jaina teaching.

The cycle is divided into five lunar years of which the first, second and fourth consist of 12, and the 3rd and 5th of 13 synodic months. The synodic month is also divided into two lunar ayanas and six lunar seasons.

The cycle commences at the summer solstice when the moon is full at the beginning of Abhijit and thus differs from the Vedānga Jyothisha. If Abhijit is to be identified with α lyrae, as it invariably has been, then the date of observation must have been about A. D. 850, when the winter solstice took place at the same longitude as α Lyrae.[71]

The sun revolves round Mount Meru always at the same height from the plane of the earth, namely 800 yojanas, but at varying distances from Mount Meru. The radius on the longest day is 49, 820 yojanas and on the shortest day it is 50,330 yojanas. The longest day is, as in the *Vedānga*

71 *Ibid.*, pp. 19-20.

Jyothisha, 18 *muhūrtas* (= 14.4 hours), and the shortest 12 *muhūrtas* (= 9.6 hours) and the daily change is 1.57 minutes, and the corresponding latitude would be about 36 degrees.

To overcome the difficulty of explaining the rising and setting of the sun it is assumed that the body becomes visible only when he is within a distance equal to half the extent of his day's journey. The moon is also supposed to move in concentric circles round Meru at a distance of 880 yojanas from the plane of the earth, that is 80 yojanas further away than the sun. It enters into conjunction with the sun 62 times and completes 67 sidereal revolutions in the five years. It is mentioned in the Sūryaprajnapti that the planets travel faster than the sun and the stars, faster than the *nakshatras.*[72]

Siddhānta:

The astronomical computations described in the *Vedānga Jyothiṣha* were in practical use for a very long time. Around the beginning of the Christian era, say a century on either side of it, a new type of Indian astronomical literature emerged. The texts representing this development are called Siddhanta. The word "Siddhānta" has the connotation of an

[72] *Ibid.*,p. 21.

established theory. These Siddhānta texts contain much more material and deal with more topics than the *Vedānga Jyothiṣha.*

Along with the Nakshatra System, the twelve signs of the Zodiac, viz., Meṣa, Vṛṣabha, etc. were introduced. A more precise value for the length of the solar year was adopted. Computations of the motions of the planets, the solar and lunar eclipses, ideas of parallax, determination of mean and true positions of planets and a few more topics formed the common contents of the Siddhāntic texts.

A very significant aspect of that period, and of the history of Indian astronomy, was the remarkable development of newer mathematical methods which greatly promoted mathematical astronomy. Needless to say, the unique advantage of the famous Hindu decimal numbers made even computations with huge numbers very simple, and even enjoyable, to the ancient Indian astronomers.

According to the Indian tradition, there were principally 18 Siddhantas: Sūrya, Paitāmaha, Vyāsa, Vāsiṣṭha, Atri, Parāśara, Kāśyapa, Nārada, Gārgya, Marīchi, Manu, Ārigīra, Lomasa (or Romaka), Pauliśa, Cyavana, Yavana, Bhrigu and Saunaka. However, among these, only five Siddhāntas were extant during the time of Varāhamihira (505 A.D.) viz. Saura (or Sūrya), Paitāmaha (or Brahma), Vāsisṭha, Romaka and Pauliśa.

These five Siddhāntas were ably compiled by Varāhamihira and preserved for posterity as his *Pancha-Siddhāntikā*.[73]

Paitāmaha Siddhānta (2nd century A.D.) retained the Vedānga astronomical system. Āryabhatta I wrote the Sūrya Siddhānta, had some Greek influence dealt with the epicyclic revolution of the earth around the sun, the nature of eclipses, reckoning of time, longitudes with the prime meridian passing through Ujjayini.[74]

Hindu Astronomical Instruments:

The only instruments of practical utility for astronomical purposes described in ancient Hindu works are the sun-dial and clepsydra. An armillary sphere is also described as an instrument for purposes of demonstration. The only Hindu instrument of any antiquity actually found is the clepsydra, consisting of a metal bowl floating in a vessel of water.

The following is a summary of those parts of the early Hindu texts that deal with astronomical instruments.

(i) The clepsydra or water clock is referred to in the *Vedānga Jyothisha*, where the amount of water that measures a *nādikā* (=24 minutes) is given. The more ancient form of water clock, appears to have been

[73] S. Balachandra Rao, *op. cit.*, p.6.
[74] *Civil Services Chronicle,* January 2007, p. 125.

simply a vessel with a small orifice at the bottom, through which the water flowed out in a nādikā, but later on there came into use the form described in the Sūrya Siddhānta (xiii, 23): "A copper vessel, with a hole in the bottom, set in a vessel of pure water, sinks sixty times in a day and night, and is an accurate hemispherical instrument". The *Pancha-Siddhantika* description (XIV, 32) is similar, but adds "or else a nādikā may be measured by the time in which sixty slokas, each consisting of sixty long syllables, can be read out". A later description of the clepsydra is as follows: "A copper vessel, weighing 10 palas, six angulas in height and twice as much in breadth at the mouth, this vessel of the capacity of 60 palas of water, and hemispherical in form, is called a ghati. The aforesaid copper vessel, bored with a needle made of 3 ⅓ mashas of gold and 4 angulas long, gets filled in one nādikā".

In practice, no doubt, the dimensions of the bowl and the orifice were determined by experiment. Bhāskara (XI, 8) indeed says: "See how often it is filled and falls to the bottom of the pail of water in which it is placed. Divide 60 ghatis of day and night by the quotient and it will give the measure of the clepsydra".

(ii) The Gnomon - The sun-dial described in the early treaties is of the simplest kind, consisting of a vertical rod, or gnomon, divided into

12 divisions. The descriptions are of a theoretical nature, and do not apply so much to the construction of instruments as to theoretical calculations.[75]

Thus, whatever may be the real facts regarding the order in which each nation might have acquired its astronomical system, there is enough material in these similarities to establish the fact that the prehistoric astronomy of the world was founded by the Aryans of central Asia.

Of the great antiquity of Indian Astronomy, the first evidence was afforded to western investigators by the publication of certain astronomical tables in the *Memoirs of the Academy of Sciences* in 1687 by M. Le Loubore, which were taken from India. These were examined by Cassini.

Two other tables were also secured by the French missionaries, when they were in India,

i *The tables of Krishnapuram and Narsapur* and

ii *The tables of Tiruvalore*, published by Le Gentil in 1772. He had come to India to observe the transit of Venus in 1769. He learnt from the pandits of Tiruvalore the method used by them in the calculation

[75] G. R. Kay, *op. cit.*, p. 67.

of eclipses etc. Another French astronomer who made a study of these tables is M. Bailly; also Professor Playfair, who studied Bailly's work, verified all the calculations and tables prepared by the latter; and it has been concluded that.

a. The observations, on which the astronomy of India is based, were made more than three thousand years Before Christ and, in particular, the places of the sun and moon were determined accurately by actual observation;

b. The construction of these tables implied a great knowledge of geometry, of arithmetic and even of the theoretical parts of spherical astronomy.[76] The real foundation of a proper knowledge of the history of Hindu astronomy was laid by Weber (1860-1868), Whitney (1858) and Thibaut (1877-1889). Weber gave us the *Vedānga Jyothisha*, etc., Whitney a translation, together with a critical commentary, of the Sūrya Siddhānta, and Thibaut the *Pancha-Siddhantika* of Varāhamihira; and with these should be mentioned Sachau's translation (1888) of *Albirūni's India*. These contributions settled definitely the question of the connection between the later Hindu astronomy and that of the Greeks, and the

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76 O. R. Walkey and H. Subramania Aiyar, *Concise General Astronomy*, Trivandrum, 1940, pp.5-6.

orientalists was consequently directed to the earlier periods that had been designated Vedic and post Vedic.[77] It is important to remember that ancient Indian knowledge on all these aspects are not merely religious or spiritual, but are purely scientific.[78]

Scientific Astronomy

Scientific astronomy might be said to have commenced when the fundamentals of the science had been established and strict rules and procedures of computation had been formalized. The system could then grow on a rational basis. In the history of astronomy, the scientific period could be said to have started towards A.D. 500, with Āryabhatta (born A.D. 476), from when on there has been a long line of recorded astronomical tradition reaching down to the seventeenth century in general and right up to the nineteenth century in remote corners in India like Kerala. This period of nearly one and half millennia produced several lines of astronomers who maintained the tradition and also made substantial original contributions, some of which were re-discovered, much later, in modern astronomy.[79]

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77 G. R. Kay, *op. cit.*, p. 5.

78 Bina Chatterjee, *Indian Astronomical knowledge 1300 years ago-Sishyadhivruddhita tantra of Lalla Charya,* Thiruvananthapuram, p. 21.

79 K. V. Sarma, A History of the Kerala School of Hindu Astronomy, *op.cit.,* pp. 1-2.

The scientific astronomy may be conveniently divided into two sub-periods, of which the earlier one only has historical importance. This may be considered to coincide pretty closely with the period of the Gupta dynasty (A.D. 320-650) and it embraces the most celebrated of the Hindu astronomers - Āryabhatta, Varāhamihira, Brahmagupta and their contemporaries. In the history of civilization generally this period is of exceptional interest. In India the period was productive of many important works in mathematics, astronomy, astrology, medicine, poetry and drama.

The second sub-period which extends from about A.D. 700 to the present day, is of sub-ordinate interest altogether in India. Bhāskara II is the only conspicuous figure and his importance has been some what exaggerated. His *Siddhānta Siromani* is, however, one of the best known of the Hindu works.[80]

Scientific astronomy can be said to have been enunciated in India by Āryabhatta I (A.D. 476), his pupil Latadeva (A.D. 505), Varāhamihira, Brahmagupta, Bhaskara I (a contemporary of Brahmagupta and a disciple of Āryabhatta I), Lalla, author of *Sisya Dhivriddhita*, Sumati (A.D. 800), author of *Sumati Tantra* and *Sumati Karana*, Manjula (A.D. 930), Āryabhatta 11 (A.D. 950), Śripati (A.D. 1039), author of the *Siddhānta Sekhara* and *Ganita Tilaka* and Bhāskara II (A.D. 1150) who wrote the

[80] G. R. Kay, *op. cit.*, pp. 8-9.

important treatise *Siddhānta Siromani*, were the Hindu astronomers and most of them also made significant contributions to mathematics.[81] Calculations based on the scientific astronomy are used even to this day with a fair amount of accuracy and ephemeredes are published in various parts of India, based upon this system of reckoning.[82]

The achievements of some of the great astronomers such as Āryabhatta I, Varāhamihira, Brahmagupta, Bhāskara I and Bhāskara II are monumental.[83]

Āryabhatta

The most famous Indian mathematician cum astronomer of yore is undoubtedly the great Āryabhatta (b. A.D. 476) whose A.D. 479 text *Āryabhattiya* (meaning Āryabhatta's work) was the first astronomical work that was attributed to a single author and accurately dated. Āryabhattiya exercised profound influence on later developments. For more than a thousand years, it was commented upon, followed, adapted, or criticized, but never ignored.[84]

Many things about him-his place of birth, his date of birth and even his real name are still subjects of controversy. The situation becomes all the

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81 H. J. J. Winter, *op. cit.*, p. 153.
82 O. R. Walkey and H. Subramania Aiyar, *op. cit.*, p. 5.
83 Priyaranjan Ray and S. N. Sen (ed.), *The Cultural Heritage of India*, Calcutta, 1986, p. 261.
84 A. Rahman (ed.), *History of Indian Science, Technology and Culture A. D. 1000-1800*, New Delhi, p. 178.

more confusing because of the indications that more than one mathematician bearing the name Āryabhatta flourished in India at various periods. That there were atleast two Āryabhattas is beyond doubt:

(i) Āryabhatta of Kusumapuram who wrote the Āryabhattiyam in 499 A.D. and

(ii) Āryabhatta who wrote the astronomical treatise called the Maha Ārya Siddhānta (950 A.D.).[85]

To distinguish between the two, the author of the Āryabhattiya is called Āryabhatta I, and the author of the Maha Siddhānta is called Āryabhatta II.[86] With regard to his place of birth, it is argued that Kusumapuram was not Āryabhatta's place of birth; which has been born out by the statement: "Aśmakajanapādajāta Āryabhattacārya" (Āryabhatta who was born in Aśmakajanapādam) contained in Nilakantha's commentary on Āryabhattiyam. It is therefore possible that Āryabhatta was born in Aśmakajanapādam and later he migrated to Kusumapuram (modern Patna).[87]

The Persian scholar Al-Birūni (A.D. 973-1043) has, on occasions more than once, called him Āryabhatta of Kusumapuram. Bhāskara I (A.D.

85 S. Parameswaran, 'Āryabhatta', in T. K. Ravindran (ed.), *Journal of Kerala Studies*, Trivandrum, 1981, p. 69.
86 K. S. Shukla and K. V. Sarma (ed.), *Āryabhattiya of Āryabhatta*, New Delhi, 1976, p. xvii.
87 S. Parameswaran, 'Āryabhatta', *loc.cit.*, p. 69.

629), the earliest commentator of the Āryabhattiya, identifies Kusumapuram with Pātalīputra in ancient Magadha, and the knowledge honoured at Kusumapuram with the teachings of the 'Svayambhuva or Brahma Siddhānta'.[88]

Magadha in ancient times was a great centre of learning. The famous University of Nālandā was situated in that state in the modern district of Patna. There was a special provision for the study of astronomy in this university; an astronomical observatory was a special feature of this university. Āryabhatta I has been designated as Kulapa (=Kulapati or Head of a University). It is quite likely that he was a Kulapati of the University of Nālandā which was in a flourishing state in the fifth and sixth centuries A.D. when Āryabhatta I lived.[89] It seems that Āryabhatta was an Aśmaka who lived at Pātalīputra (Modern Patna) in Magadha (Modern Bihar) and wrote his Āryabhattiya there.[90]

There are different opinions from various scholars regarding to his place of birth and it is a controversial subject. Some scholars prove him to be of Keralese origin but some others disapprove it.

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88 K. S. Shukla and K. V. Sarma (ed.), *op. cit.*, p. xviii.

89 *Ibid.*, p. xix.

90 T. S. Kuppanna Sastri and T. Chandrasekharan (ed.), *Mahabhaskariya of Bhāskaracarya*, Madras Government oriental series No. cxxx, Madras, 1957, p.xii.

The facts supporting it are:

(1) The Āryabhattan School is specially associated with Kerala country. Practically all the astronomers of this school whose place of origin can be definitely determined belong to this part of India and also as all the astronomical works produced in Kerala, whether commentatorial or original treatises, follow the Āryabhattan school; also manuscripts of the works of this school are found mostly only in this part of the country. Probably Āryabhatta himself was a native of Kerala. He is called Aśmaka which is derived by commentators as belonging to the Aśmaka country. And in some quarters it is identified with the southern part of Kerala state.[91] The region of Aśmaka as the place where he hailed has been taken as a sanskritisation of the Malayalam place name Kotunnallur in central Kerala.[92] As for his connection with Kusumapuram (Pātalīputra) it is not as a native of that city, but as one who has adopted the Siddhānta venerated and followed by the people of Kusumapuram.[93]

(2) Āryabhatta has dated the year of composition of Āryabhattiyam in the Kali era.[94]

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91 K. S. Shukla and K. V. Sarma (ed.), *op. cit.*, p. 71.
92 K. V. Sarma, A History of the Kerala School of Hindu astronomy, *op. cit.*, p. 8.
93 T. S. Kuppanna Sastri and T. Chandrasekharan (ed.), *op.cit.*, p.xii.
94 K. V. Sarma, A History of the Kerala School of Hindu astronomy, *op. cit.*, p. 72.

Drkkarana, an astronomical manual composed in Malayalam verse in A.D.1607-08, written by Jyeṣṭhadeva, author of the astronomical treatise *Yuktibhāsa* throws some interesting light in this direction.

tadā hy Āryabhato nāma ganakas tv abhavad bhuvi /

'Jnānatunge' ti Kalyabde jātanāy avanitale //

'Then, in the Kali year jnānatunga (3600 = A.D. 499) and astronomer by name Āryabhatta was born in this world.

giritungeti Kalyabde ganitam nirmitam param /

sāstram Āryabhatīyākhyam tasmin paryayam uktavān //

'In the Kali year giritunga (3623 = A.D. 522) was his work Āryabhattiya composed and therein he stated the revolutions of the planets.[95]

In the whole of India, it was only in Kerala and to some extent in the bordering areas of the Tamil country where Kali era and only Kali era was in common use; elsewhere in India the Vikram era and Saka era (founded in B.C. 58 and A.D. 78 respectively) were in vogue. Kollam era of Kerala, which is also in use now, was founded only in A.D. 825. Prior to that

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95 *Ibid.*, p. 9.

astrologers, astronomers, mathematicians, scholars and writers of Kerala were using Kali era.[96]

The facts disapproving it are:

(1) The beginnings of astronomical and mathematical studies in Kerala are shrouded in obscurity. K. Kunjunni Raja mentions in his book "Astronomy and Mathematics in Kerala" that some enthusiastic scholars have claimed for Kerala the great Āryabhatta and Bhāskara I on the grounds that practically all the important astronomical and mathematical works produced in Kerala follow the Āryabhattan School, and that works of these ancient authorities have been very popular in that part of India as indicated by the existence of a large number of manuscripts and commentaries there. This claim does not seem to be tenable, for the Āryabhattiya does not contain any reference to Kerala, on the other hand it refers to Kusumapuram (Pātalīputra), though it is not definitely stated that the author belonged to that city. In the case of Bhāskara I it is true that he has been more popular in the South than in the North, but in his works he refers to places like Valabhi, Sthānvīśvara and Ujjayini, but not to any place in Kerala. Even popular traditions in Kerala do not claim these two scholars as belonging to that state. According to these

96 K. N. Menon, *Āryabhatta,* New Delhi, 1977, p. 57.

traditions the legendary astrologer-astronomer Vararuci is associated with the introduction of this science to Kerala.[97]

(2) Bhāskaracharya calls him as 'Asmakiya' but it is not clear about where the Aśmaka is! And this identification became critical through years.

(3) Even after sixty years from independence, there is no scientific evidence about Āryabhatta his place of birth, his date of birth and even his real name are still subjects of controversy.[98]

Whether Āryabhatta was a native by birth of Kerala or not, may remain a subject of controversy but the hold that Āryabhattiyam had on the later mathematicians cum astronomers of Kerala was without an equal; Āryabhattiyam seems to be the one fountain head from which mathematicians cum astronomers of Kerala not only drank deep but also drew their inspiration for many centuries to come. Hence an analysis of the contents of Āryabhattiyam is not only justifiable but has turned out to be a must as a prerequisite for the further study of Keralese School of mathematics and astronomy.[99]

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[97] K. Kunjunni Raja, *Astronomy and Mathematics in Kerala*, Adyar, 1963, pp. 119-120.
[98] *Mathrubhumi Illustrated Weekly*, September 23-29, 2007, pp. 9-10.
[99] S. Parameswaran, 'Āryabhatta', *loc.cit.*, p. 73.

Āryabhatta and Scientific Indian Astronomy

Scientific astronomy can be said to have been enunciated in India by Āryabhatta I, through his two works, the *Āryabhatta-Siddhānta* which is available only in the form of citations by later authors, and as summarized in the *Khandakhadyaka* of Brahmagupta, and the *Āryabhattiya,* a full fledged work composed in A.D. 499. Āryabhatta was an observer par excellence and, as a result of his investigations, he revised the then current astronomical parameters, introduced new techniques in calculation and established Hindu astronomy on a scientific basis.

Āryabhattiya

The Āryabhattiya, couched in 121 aphoristic verses is the earliest extant Indian treatise on scientific planetary astronomy. Its first section, called Gitikā -pāda, sets out in 13 verses the basic definitions, the main astronomical parameters, the zero point for the commencement of calculations, the positions of the apogees and the ascending nodes of the planets at the time of the author, the diameters of the earth and the planets, the obliquity of the ecliptic and the inclinations of the planetary orbits to the ecliptic and a table of sine differences. The second section, Ganitā-pāda, in 33 verses, is concerned with enunciations involving arithmetic, geometry and trigonometry. The third section, Kālakriya-pāda, in 25 verses, gives the

units of time, explains the motion of the planets by means of epicycles and enunciates the methods for the determination of the mean and true positions of the planets at any given time. The fourth section, Gola-pāda, in 50 verses, deals with the motion of the sun, moon and the planets on the celestial sphere and the computation and graphical representation of the solar and lunar eclipses.

Āryabhatta's Contribution

Āryabhatta's contribution to algebra, trigonometry and astronomy are highly significant. Among them a special mention might be made of the theory of indeterminate analysis of the first degree, the value of π correct to four decimal places, the computation of the sine table, the use of the radian measure of 3438 minutes of arc, advanced astronomical parameters, the theory of planetary motion and the correct interpretation and computation of the eclipses.[100] Āryabhatta I contained a chapter on algebra in the Āryabhattiya, which was used by Al-Birūni.[101]

Earth's Rotation

Āryabhatta made significant contributions to the field of astronomy. He also propounded the heliocentric theory of gravitation, thus predating

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100 K. V. Sarma, A History of the Kerala School of Hindu astronomy, *op. cit.*, p. 4.
101 *Civil Services Chronicle*, p. 125.

Copernicus by almost one thousand years.[102] Āryabhatta promulgated the theory of the rotation of the earth. Against the current view that the earth was stationary at the centre of the universe and that all heavenly bodies revolved around it, Āryabhatta held that the earth rotated round its axis once in a sidereal day[103] and through an angle of one minute of arc in one *prana* (equal to $\frac{1}{6}$ of a *vinadi*, or 4 sidereal seconds),[104] while the stars were fixed in space.[105] The time for one sidereal rotation of the earth at the above rate would work out to $23^h\ 56^m\ 4^s.1$, while the corresponding modern value is $23^h 56^m 4^s.091$. The accuracy of Āryabhatta's enunciation is remarkable.

Opposition to Āryabhatta

It is a highly interesting and, perhaps, instructive anecdote in the annals of Indian astronomy that the above theory of Āryabhatta is known to us from the writings of contemporary and later critics of Āryabhatta like Varāhamihira (A.D. 505), Brahmagupta (A.D. 628), Lalla (8^{th} cent.), Śripati (A.D. 1039) and Bhāskara II (b. 1114), who severely criticized Āryabhatta's theory of the rotation of the earth.[106]

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102 www.sudhanshu.com /history.htm.

103 Kripa Shankar Shukla, *Āryabhattiya of Āryabhatta,* New Delhi, 1976, Kalakriya, Verse. 5, p. 91.

104 *Ibid.,* Gitikā, Verse. 6, p. 13.

105 *Ibid.,* Gola, Verse. 9, p. 119.

106 K. V. Sarma, A History of the Kerala School of Hindu astronomy, *op. cit.,* pp. 5-6.

Decline and Resurgence of the System

Severe criticism, both veiled and open, against the system of Āryabhatta, coming as it did from acknowledged authorities, like Brahmagupta, Varāhamihira and Śripati, should have be devilled not only the laymen but also the professionals, and the study of Āryabhattan System gradually declined in North India. And, with the wide popularity gained by the great works of Bhāskara II (b. 1114) who followed in the wake of Brahmagupta and Śripati, the Āryabhattan System was practically effaced from North India.[107]

The Āryabhattan System, however, emerged with increased vigour south of the Vindhyas. The superiority of the astronomical parameters and the novel innovations of Āryabhatta had given rise to a 'School of Āryabhattan Astronomy', the followers of which called themselves Asmakiya-s (advocates of the school of the Aśmaka author, viz., Āryabhatta) or Bhatasisyas (students of Āryabhatta). Scholars of South India, comprising of Karnataka, Andhra, Tamilnadu and Kerala, avidly took to the study of the Āryabhattiya and produced several commentaries and a mass of literature based on the system of Āryabhatta.[108]

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107 *Ibid.*, p. 7.
108 K. S. Shukla and K. V. Sarma, *op. cit.*, pp.xxxv– xxxvii

Kerala adopted the basic tenets and practices of Āryabhattan astronomy. Practically every astronomical text produced in the land bases itself on the teachings of Āryabhatta. The efforts of Kerala mathematicians have been directed also towards the revision, correction and supplementation of Āryabhattan astronomy with a view to arriving at more accurate results.[109]

Varāhamihira

Varāhamihira is a contemporary astronomer of Āryabhatta I.[110] The ancient world is known through via the Siddhāntas or the astronomical treatises which in themselves exhibit a transition from the Paitāmaha Siddhānta, which retains the Vedānga astronomy, to the Sūrya Siddhānta of A.D. 400, which largely establishes the form of native astronomy for the duration of the Middle Ages. Varāhamihira A.D. 505 summarised in his *Pancha-Siddhāntika* the five Siddhāntas entitled *Paitāmaha, Vāsishtha, Pauliśa, Romaka and Sūrya.*[111]

Greek astronomical ideas were transmitted to India during the first four centuries of the Christian era. This period coincides with that of the growth of the Siddhānta literature, and the Romaka Siddhānta especially

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109 K. V. Sarma, A History of the Kerala School of Hindu astronomy, *op. cit.*, p. 8.

110 S. A. S. Sarma, "Āryabhatta: His Name, Time and Provenance: Their Identification", *International Seminar on Āryabhatteeyam*, January 12-16, 2000, Thiruvananthapuram, p.59.

111 A. L. Basham, *op. cit.*, p. 151.

shows signs of Greek influence, an influence which is notably present in the terminology of astrological writings such as the *Brihajjataka* and *Laghujātaka* of Varāhamihira.[112] The *Brihajjataka* of Varāhamihira which is popularly known as Hora is an authoritative work on Astrology.[113] It was also the period of close commercial intercourse between imperial Rome and the coasts of Kerala and Tamilnadu, embracing both the Augustan age and the Sangam age.

The Sūrya Siddhānta, in addition to the use of terminology and units of Greek origin, employs epicyclic models in its planetary theory which proves that the planet moves on an epicycle of radius r which is carried on a circle of radius R and eccentricity e, the 'deferent' around the observer. Thus we are dealing with two variables, the 'mean distance' α of the centre of the epicycle from the apogee of the deferent, and the 'anomaly' r which determines the position of the planet on the epicycle. The problem now arises to tabulate this rather complicated function of α and γ. Into this Greek geometrical system the Hindus injected the important concept of the sine of an angle, thus initiating a second tradition which may be called as 'trigonometrical'. Both the Pauliśa and Sūrya Siddhāntas contain a table of sines.[114]

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112 T.K.Gangadharan, *Evolution of Kerala History and Culture,* Calicut, p.130.
113 T.K Ramachandra Aiyar, *A Short History of Sanskrit Literature*, Palghat, 1995, p. 185.
114 A. L. Basham, *op. cit.*, p. 152.

Varāhamihira mentions that among the five systems of Pancha Siddhāntika - Paitāmaha, Vāsishtha, Pauliśa, Romaka, and Sūrya. The Sūrya Siddhānta is the best. Even to this day the most popular astronomical text is Sūrya Siddhānta, though in its revised form. It is believed that the modern version of Sūrya Siddhānta was composed around 1000 A.D.[115]

The chapters of the Sūrya Siddhānta deal with the mean motions of the planets, the true positions of the planets, direction, place, and time, the nature of eclipses, planetary conjunctions, asterisms, heliacal risings and settings, the rising and setting of the moon, certain malignant aspects of the sun and moon treated in part astrologically, cosmogony, geography, and the dimensions of the creation, measuring instruments such as armillary sphere, clepsydra, and gnomon, and different ways of reckoning time.

Highly regarded and widely disseminated, the Sūrya Siddhānta had a profound influence on the course of medieval Hindu astronomy. According to Sumati (A.D. 800), whose work was known both in Nepal and in Kerala, and who wrote his *Sumati tantra* and *Sumati karana* on the basis of the earlier version of the Sūrya Siddhānta, it provided the essential elements used by Nepalese astronomers in their construction of the Hindu calendar. Evolving during the period between A.D. 628 and 966, the later version gained greatly in popularity, especially in the twelfth century, when

[115] S. Balachandra Rao, *op. cit.*, p. 10.

Bhāskara II quoted from it and Mallikarjuna Suri wrote commentaries on it, first in Telugu then in Sanskrit. K. S. Shukla lists a minimum twenty eight commentaries on it.

Brahmagupta

Brahmagupta was born in 598 A.D. whilst Āryabhatta I excelled as an observer and in the classification of astronomical data; Brahmagupta was stronger as a mathematician. Brahmagupta wrote the *Brahmagupta Siddhānta* (mostly astronomy), *Dhyana-Grahopadesadhyaya* and his most important mathematics books *Khandakitadyaka* and *Uttarakhandakhadyaka* *patiganita* = science of arithmetics and geometry. Bijaganita = algebra.[116]

The astronomical writings of Brahmagupta were known in Western India at the time of the Muslim invasion of Sind (A.D. 712) and also to Abū Raihān-al-Birūni on his Indian journey some three centuries later, and there is little doubt that they were one of the media through which Hindu astronomy and mathematics passed to the Arabs during the 'Abbāsid Caliphate' through whom it spread to many countries of Europe. Al-Birūni records this testimony in his great book on India.[117] The Arabs transmitted to the west the so called Hindu numerals and decimal system and the simpler algebraic and trigonometrical processes, but ignored the use of

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116 *Civil Services Chronicle*, p.125.
117 Satya Prakash, *Brahma Gupta and His Works*, New Delhi, 1968, p. 1.

negative quantities and the higher algebra of indeterminate equations which they do not appear to have understood.[118]

Bhāskara I

Little is known about Bhāskara's place of birth, parentage or private life. He seems to have been forgotten after sometimes in the North and only recently has he come to be known there again.

In the South, on the other hand, Bhāskara I and his works have been well-known amongst astronomers. In Kerala he has always been widely known amongst astronomers as the interpreter of Āryabhatta and next only to him in importance. It is in Kerala that his works are extent and his commentators like Govindasvāmin, Sankaranārayana, Parameswaran and Narayana are all astronomers hailing from this part of the country.[119]

Date of Bhāskara

There are controversies regarding the date of Bhāskara. The scholars were of different views about it. Some scholars regard Bhāskara as the direct pupil of Āryabhatta who wrote the Āryabhattiya in A.D. 499 but others consider that Bhāskara could not have been a direct pupil of Āryabhatta.

118 A. L. Basham, *op. cit.*, p. 156.
119 T. S. Kuppanna Sastri and T. Chandrasekharan (ed.), *op. cit.*, p. xii.

From the evidence in his Bhāsya on the Āryabhatiya and from the date of Bhāskara's *Laghubhāskariya*, which was composed 23 years after the composition of the Āryabhattiya, it can be concluded by fixing the upper limit to Bhāskara's date at A.D. 550 and the lower limit may be fixed as A.D. 628, the date of Brahmagupta's *Brahmasphuta Siddhānta* from the following considerations[120] that he could be the grand pupil of Āryabhatta, redactor and commentator, who is perhaps, the best authority in the matter, on account of his chronological proximity, besides being a propagator of the Āryabhattan school.[121]

Bhāskara and his works

The *Mahabhāskariya* is an important work in Indian astronomy written by Bhāskara I who must be distinguished from the later and well known Bhāskaracārya II, author of *Lilavati*, *Bijaganita* and the *Siddhānta Siromani* (A.D. 1150). Bhāskara I has written three works, the *Mahabhāskariya*, the *Laghubhāskariya* and a *Bhāsya* on the Āryabhattiya. He seems to have intended the *Mahabhāskariya* as an exposition on the Āryabhattiya, as well as an independent work. The *Laghubhāskariya* is an epitome of the *Mahabhāskariya*.

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120 *Ibid.*, p. xvi.
121 S. A. S. Sarma, *op. cit.*, p. 62.

The real name of Mahabhāskariya

Though popularly known by the names *Mahabhāskariya* and *Brhad-Bhāskarīya*, the name intended by the author to the work is *Karmani bandha*, 'a treatise on astronomical calculations'. Whereas his Āryabhattiya - Bhasya is called *Brhat-Karmani bandha* to distinguish it from the *Laghu-Karmanibandhu* used with reference to the third work of Bhāskara, the *Laghu-Bhāskarīya*.[122]

The school of Āryabhatta

Though Bhāskara I was not a direct disciple of Āryabhatta, it is certain that he belonged to the school of Āryabhatta and was one of its important exponents.[123] That Bhāskara identified himself with this school is quite apparent. He refers to Āryabhatta in his Bhāsya as "our preceptor", Asmakamacharya, in several places. When in one place he says, "For us the four quarters of the Yugas are equal", *asmakam punāh yuga patha sarva ēvathulayaha*, he identifies himself with the teacher and his school.[124]

As far as the place from where Bhāskara I hailed and settled down in later life to write his works, there is no sufficient evidence to state anything definitely. While K. S. Shukla is of the opinion that there are, however,

[122] T. S. Kuppana Sastri and T. Chandrasekharan (ed.), *op. cit.*, p. xi.
[123] S. Parameswaran, 'Āryabhatta', *loc.cit.*, p. 205.
[124] T. S. Kuppana Sastri and T. Chandrasekharan (ed.), *op. cit.*, p. xx.

reasons to believe that Bhāskara I belonged to the Aśmaka country and that he lived and taught at Valabhi in Surastra (modern Saurastra or Kathiawar) where he wrote his commentary on Āryabhattiyam, scholars like A. N. Singh of Lucknow hold that there is sufficient justification to state that Bhāskara was a native of Kerala.

Another opinion runs as follows: 'stray references to his (Bhāskara I's) works appear to indicate his association with Surastra (Western India) and Aśmaka (South India, probably Kerala). It is possible that he was a native of either of these two regions and migrated to the other'. But there are no accurate evidences to prove these facts.

Bhāskara I earned great name and fame as a teacher of astronomy and his works continued to be studied in South India and several commentaries came to be written by South Indians especially Keralese - Scholiasts such as Govindasvāmin (800-850 A. D.), Sankaranārayanan (825-900 A. D.), Udayadivākaran (11th century) and Parameswaran (1360-1455 A. D.).[125] The achievements of Āryabhatta, Varāhamihira, Brahmagupta and Bhāskara I are monumental.

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[125] S. Parameswaran, 'Āryabhatta', *loc. cit.*, pp. 205-206.

Bhāskara II

Bhāskara II was a mathematician. In India indeterminate analysis reached its zenith in Bhāskara II. He obtained whole number values of x and y which satisfy the equation $ax \pm by = c$.

Indeterminate equations of the second degree in the forms;

$$ax + by + c = xy$$
$$\text{and} \quad ax^2 + c = y^2$$

had already been investigated by Brahmagupta, but the solution of the general equation.

$$ax^2 + bx + c = y^2$$

by the chakravāla or cyclic method, was effected by Bhāskara II in a manner which has perpetuated his name for all time in the history of the theory of numbers. It is salutary to remember that Bhāskara II made these advances around the middle of the twelfth century, independent European investigations, of the seventeenth and eighteenth centuries did not reach completion until about 1770, with the work of Euler and Lagrange.

The delightful *Lilavati* and *Bijaganita*, which form part of the *Siddhānta Siromani* of Bhāskara II, have been widely used since their composition. A Persian version of *Lilavati* appeared in 1587 on the orders

of Akbar and one of *Bijaganita* in 1635 for Shāh Jahān. *Lilavati* was later rivaled by the *Ganita Kaumudi*, composed in 1356 by Nārāyana, a work notable for its treatment of magic squares. Indian interest in magic squares is reflected in Siamese mathematics of the seventeenth century.[126]

Little, if any, astronomical activity existed in India over the next five centuries until Jai Singh (1686-1743) performed the incredible feat of building five observatories and making accurate observations with them in a little less than four decades. These institutions contain enormous instruments of masonry, many of which were invented by Jai Singh himself such as jai prakās and ram yantra and samrāt yantra, the semi diameter etc. and were meant to mutually confirm and check the observations made. Though magnificent in concept, they were seldom used after Jai Singh, and with the new era of telescope technology already a hundred years old, they retreated rapidly into obsolescence.[127]

In astronomy the Muslim tradition of instrumental technology survived in India until the middle of the eighteenth century. The astrolabe, which has been lovingly perfected by generations of Persian and Arab craftsmen and was again executed in fine workman ship by the family of 'Īsāb' Allahabad in Lahore in the reign of the Mughal Emperor Jahāngir

126 A. L.Basham, *op.cit.*, p.157.
127 Priyaranjan Ray and S. N. Sen, *op.cit.*, p. 261.

(1605-27), was used by the astronomers in the service of the Maharaja Sawai Jai Singh II (1686-1743) at his observatories in Delhi, Jaipur, Ujjain, Varanasi (Benares), and Mathura. Though Jai Singh's principal astronomer was the Hindu Jagannath he made full use of European and Islamic ideas. In particular his massive masonry quadrants and dials, constructed to attain maximum accuracy, in the absence of the telescope in India.[128]

Though with Bhāskara II ended the great era of mathematics in North India, Kerala continued to make its mark in the field. The achievements of some eminent astronomers of Kerala have been particularly remarkable as is evinced by the numerous contributions of various scholars in astronomy and astrology.[129]

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128 A. L.Basham, *op.cit.*, p.158.
129 N. Narayanan Namboodiri (ed.), *Karanamrtam*, University of Kerala, 1975, p.i.

CHAPTER - 2

DEVELOPMENT OF ASTRONOMY IN KERALA

Kerala had made substantial contributions in the field of traditional Hindu astronomy both observational and computational starting from the fourth century A.D. A sound mathematical and observational basis to the Indian astronomy was first provided by Āryabhatta and Kerala school of Hindu astronomy was developed from his ideas.[1] The medieval period of Kerala history is noted for its significant contributions in the field of mathematics and astronomy.[2] It is well known from time immemorial Kerala has been an exclusive repository of ancient, original and valuable manuscripts in the field of mathematics and astronomy.

Though with Bhaskara II ended the great era of mathematics in North India, Kerala continued to make its mark in the field. Indeed the achievements of some eminent astronomers of Kerala have been particularly remarkable as is evinced by their numerous contributions to astronomy and astrology.[3] The almost legendary figure Vararuci, the author of *Candravākyas* and the others like Talakkulathu Govinda Bhattatiri, the founder and pioneer of astrology in Kerala, Sangamagrāma Mādhava, Parameswaran of Vatasseri (1360-1455) who composed the *Drigganita*

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1 T. E. Girish, *op.cit.*, p. 145.
2 A. Sreedhara Menon, *Social and Cultural History of Kerala*, New Delhi, 1979, p. 366.
3 V. Narayaran Namboodiri (ed.), *op.cit.*, p. i.

deserve special mention. Nilakantha Somayajin (1444-1545) of Trikkandiyur wrote the *Tantra Samgraha*, *Aryabhattiyabhashya*, *Grahananirnaya*, *Chandradichayaganita* and *Golassara*. In these works Nilakantha deals with all aspects of astronomy in the most comprehensive manner. He expounds the theory of eclipses and sets out the procedure for the observation of planets.

Trikkandiyur Achuta Pisharati (1550-1621) wrote about a dozen works on Jyothisha which include the *Karanottama* on astronomical computation, *Uparagakriyakrama* on eclipse computation and *Horasarochaya* on horoscopy. Thus Kerala produced a galaxy of savants who made significant contributions in the fields of mathematics, astronomy and astrology through their scholarly works.[4] At least the Katapayādi system of notation, the introduction of the Drk School of computation and the discovery of the infinite series Π (the ratio of the circumference of a circle to its diameter) are well known contributions of Kerala to astronomy. The most important scientific work produced during the medieval Kerala is the *Sankaranarayaneeyam* of Sankaranarayana. This work gives all details about observation of the sky, about mathematics and also about the city of Mahodayapuram, the capital of the Cheras.[5]

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4 A. Sreedhara Menon, Social and Cultural History of Kerala, *op. cit.*, p. 366.
5 T. K. Gangadharan, *op.cit.*, p. 130.

What is most striking is that when mathematical studies elsewhere in India languished with the end of the epoch of Bhaskara, Kerala kept the torch burning bright in this field of knowledge. Apart from elaborating and improving upon the Āryabhattiya School of astronomy, Kerala evolved its own schools of astronomy like the *Parahita* and *Drigganita* systems which had their own distinct advantages.[6]

The astronomical studies started by Sankaranarayana and others during the Perumal period had been carried over by the succeeding generations also. Vatasseri Parameswaran Namboothiri was a famous astronomer of the medieval period. The astronomical work *Parahita Sidhanta*, a revised version of the theories of Āryabhatta was very popular in medieval Kerala. The theories of Āryabhatta were used by astronomers like Vatasseri Namboothiri to explore new spheres in the '*Drigganita* System' of astronomy.[7]

Vararuci I (4th century A.D.)

Vararuci can be regarded the father figure in the astronomical tradition of Kerala. He is supposed to have lived during the first half of the fourth century A.D. To Vararuci is ascribed the authorship of the 248 *candravākyas* used for locating the true position of the moon. These *vākyas* have been very popular in South India from the days of Vararuci and were

6 A. Sreedhara Menon, Social and Cultural History of Kerala, *op.cit.*, p. 377.
7 T. K. Gangadharan, *op.cit.*, p. 176.

taught to the children in the primary stage of education. These *vākyas* are counced in the Katapayadi System promulgated by Vararuci.[8]

The *candravākya-s* is also known as *vararucivākyas.* These have been very popular in South India from ancient times and were used for the calculation of the positions of the sun and the moon, i.e. the *tithi* and the *naksatra* of each day; this calculation was considered as the minimum daily duty of a pious Hindu in Kerala.

Basic features of Kerala astronomy

From the seventh century onwards, Kerala became the bastion of the Āryabhattan School of Astronomy. While the view expressed in certain quarters that Āryabhatta hailed from Kerala has yet to be substantiated.[9] There is no doubt about the extensive popularity of the system in Kerala. The later Kerala schools are all based on the Āryabhattan System. Most of the known commentaries on the Āryabhattīya have been written by Kerala mathematicians and the scores of astronomical works produced in Kerala follow the *Āryabhattīya* basically. And, the efforts of Kerala mathematicians have generally been directed towards the revision, supplementation and correction of Āryabhattan astronomy and mathematics with a view to deriving more accurate results.[10]

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[8] S. Parameswaran, "Kerala's contributions to Mathematics and Astronomy", *loc.cit.,* pp. 142-143.
[9] K. Damodaran Nambiar, 'Aryabhatan', *Mathrubhumi*, Kozhikode, Kerala, October 15, 1970, pp. 15-16, 41.
[10] K. V. Sarma, *Contributions to the Study of the Kerala School of Hindu Astronomy*, Hoshiarpur, 1977, p.6.

Occasional disagreements found between astronomical theory and observations have motivated Kerala astronomers to do periodic revisions in their computational models. The calculation of the orbital parameters of moon by Vararuci is in close agreement with modern observations of the same. A system of astronomical computation (for making almanacs etc.) called *Parahita* System proposed by a Keralite namely Haridatta replaced the *Āryabhattan* system. *Parahita* System was later replaced by *Drigganita* System of Parameswaran (an astronomer who lived in the present Malappuram district of Kerala) during the fifteenth century. The above system is an accepted model for traditional almanac making in India, even today. *Drigganita* was a result of 55 years of continuous astronomical observations made by Parameswaran on the banks of the river 'Bharatapuzha'. After the advent of the new system, both the systems (the Drk and the Parahita) came to be used simultaneously.[11]

Katapayadi System

There are different systems of numerical notation prevalent in ancient India; of these the two popular ones are the *Katapayadi* and the *Bhūtasamkhyā*. In the Bhūtasamkhya, the numbers are indicated by well known objects. Thus 'eyes' or 'hands' indicate 2, the 'senses' or 'element' indicate 5, etc. Both Katapayadi and Bhūtasamkhyā are used by the

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[11] T. E. Girish, *op.cit.*, p. 146.

astronomers in Kerala; Katapayadi is well known in the South and is most popular in Kerala. *Candravākyas* of Vararuci and *Granhacāranibandhana* of Haridatta employ this system. It is generally believed to be one of the major contributions of Kerala to Indian mathematics.[12]

An extremely convenient method of expressing numbers through letters, known as the *ka-ta-pa-yādi* notation, has been extensively used in Kerala from early times. In this notation, each of the four series of consonants beginning with k, ṭ, p, and y in the Sanskrit alphabet stands for the digits 1 to 9. The letters k to jh indicates 1 to 9 respectively; so also ṭ to dh; p to m stand for 1 to 5 and y to ḷ represent 1 to 9 respectively. In conjunct letters, the value only of the final consonants is to be taken into account. Vowels following the consonants have no value .n and ñ and the pure vowels stand for zero.

The letter ḷ, which is peculiar to Dravidians, denotes 9. The versatility of the notation rests in the fact that even long and intricate numbers can be expressed through apparently meaningful expressions and verse bits, facilitating their easy verification and memorization. The numerous sine and other mnemonic tables which form a characteristic feature of the Kerala School of astronomy are couched in this notation.[13]

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12 K. Kunjunni Raja, *Astronomy and Mathematics in Kerala*, *op.cit.*, p. 122.
13 K. V. Sarma, Contributions to the Study of the Kerala School of Hindu Astronomy, *op.cit.*, p.6.

This system is quite convenient; as it enables one to make brief chronogram which has a connected meaning and sound pleasant making them easy to remember. And for any number it is possible to have several different chronograms. All the mathematical tables used in Kerala are written in the Katapayādi system of notation.[14] This scheme known as the Kerala System of Katapayādi was in use in South India and was extensively popular in Kerala. It is generally believed to be one of major contributions of Kerala to Indian mathematics.[15]

Haridatta (650-700 A.D.)

A significant event in the astronomy of Kerala is the promulgation of the *Parahita* System of Haridatta in 683 A.D. The revised system, which came to be known as *Parahitaganita* has been enunciated by Haridatta in his *Grahacāranibandhana* and *Mahāmārganibandhana.* This was the first major revision in the astronomical constants enunciated by Āryabhatta. Instead of Āryabhatta's complex system of notation the simpler Katapayādi System prevalent in Kerala is used. Haridatta is referred to as an authority by Kerala astronomers like Sankaranārāyana and Nilakantha; even Tamil writers like the author of *Vakyakarana* and its commentator Sundararaja mention him with respect. The *Parahita* System has been very popular in Kerala; and even after the advent of the more accurate *Drigganita* System

14 K. Kunjunni Raja, Astronomy and Mathematics in Kerala, *op.cit.*, p. 123.
15 S. Parameswaran, "Kerala's contributions to Mathematics and Astronomy", *loc.cit.*, p. 138.

introduced by Parameswaran in the fifteenth century, the *Parahita* System has been in use for religious purposes for the calculation of *muhurtas* and *sraddha* days, even now the local (pancanga-s) almanacs give positions of the planets according to both the calculations. The basic text of the *Parahita* System is the *Grahacāranibandhana*. Regarding the exact significance of the term *Parahita* there has been difference of opinion. According to the Malayalam commentary on the *Sadratnamālā* the term indicates that the system was accepted by all including the laymen. The term *parahitahetoh* used by Haridatta in the last verse of the text seems to support this view. The introduction of the simple Katapayadi notation was evidently intended to make the system easy even to the ordinary student.

Haridatta also introduced in Āryabhatta's System certain corrections known as Sakābdasamskāra or Bījasamskāra and later writers have referred to it as Haridatta's correction. According to a statement by Neelakanta Somayajin it was Sankaranārāyana and his patron, King Ravivarma Kulasekhara of Mahodayapuram, popularized in Kerala the correction called Sakābdamskāra. Haridatta's system has been quite popular in Kerala and other parts of South India, but not in the North; and there is no doubt about his being a South Indian. It is possible that he belonged to Kerala

itself, though the popularity of the system introduced by him is due to the efforts of Sankaranārāyana and his patron, King Ravivarma.[16]

Parahita System of Astronomy (A.D. 683)

The first major revision, in Kerala, of the astronomical constants enunciated by Āryabhatta was effected in A.D. 683-84 by a set of astronomers who gathered for the Māmānkam (Mahamagha) festival at the religio-educational centre of Tirunāvāy in Northern Kerala once in twelve years.[17] The council of astronomers held at Tirunavay in 682 A.D. corrected and brought up to date Aryabhatta's *Parahitaganita*.[18] These astronomers devised a system. The revised system, which came to be known as *Parahita-ganita* has been enunciated by Haridatta in his *Grahacāranibandhana* and *Mahāmārganibandhana*.

'This system was termed *Parahita* and many followed it, assuring them of its accuracy'. The promulgation of *Parahita*, being the revised Āryabhattan system, is recorded thus; in another Keralite astronomical work i.e. *Sadratnamālā* of Sankaravarman (A.D. 1800-38). When Āryabhattan results tended to be inaccurate as not tallying with observation, a correction was decided upon by astronomers for all planets other than the

[16] K. Kunjunni Raja, Astronomy and Mathematics in Kerala, *op.cit.*, p. 126.
[17] K. V. Sarma, Contributions to the Study of the Kerala School of Hindu Astronomy, *op.cit.*, p. 10.
[18] Krishna Chaitanya, *India-The Land and the People-Kerala,* New Delhi, 1972, p. 40.

sun. The revised system was known as *Parahita* because it was acceptable to all.[19]

Computation

Haridatta based his system on the Āryabhattiya, but improved upon it in several ways. He made computation easier by specifying simple multipliers and divisors for the various calculations, including the derivation of the positions of the planets. His use of the Katapayādi notation made his composition elegant. He introduced the unique system of enunciating graded tables of the sines of the arcs of anamoly and of commutation of the different planets (*Manda-jya* and *Sighra-jya*) at intervals of $3^{\circ}45'$, to facilitate the computation of the true positions of the planets. His Grahacāranibandhana being only the computation manual of the system deals mainly with the calculation of the kali days elapsed, *tithi* and *naksatra* of any day, the mean and retrograde motion of the planets and their mean and true positions. One of the corrections introduced by Haridatta to make Āryabhattan results more accurate, is called Bhata-samskāra or Sakābda-samskāra (on account of its being calculated for the years beginning from the 'S'akābda' of Āryabhatta viz., 444), and is particularly significant. This correction specifies that for every completed year after saka 444, a correction in minutes (Kalā) of -9/85, -65/134, -13/32,

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19 K. V. Sarma, Contributions to the Study of the Kerala School of Hindu Astronomy, *op.cit.*, pp. 10-11.

+45/235, +420/235, -47/235, -153/235 and +20/-35 should be made to the Mean positions of the Moon, Moon's apses, Moon's node, Mars, Mercury, Jupiter, Venus and Saturn, respectively, no correction being necessary in the case of the Sun.[20]

Drk System of Astronomy

The Drk System promulgated by Parameswaran of Vatasseri (1360-1455), through his *Drigganita*[21] is a revision of the *Parahita* system and was composed with a view to make the results of computation accord with observation. This is the author's magnum opus. Prior to the advent of the Drk System (system expounded in the *Drigganitam*), the system of astronomical computation that prevailed in Kerala was the Parahita System.

Parahita System of computation gained great popularity and was playing a leading role in the propagation and practice of astronomy in Kerala. The necessity of revising the *Parahita* System became apparent some centuries later, when due to the accumulation of minute errors in the fundamentals during the course of years, the results of computation were found to differ appreciably from those of actual observations. It was under these circumstances that Parameswaran started on his investigations which

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[20] K. V. Sarma, Contributions to the Study of the Kerala School of Hindu Astronomy, *op.cit.*, pp. 8-9.

[21] Parameswaran, Drigganita (prose), Palmleaf, No. 21772, Kerala University Oriental Manuscript Library, MSS.

led him to the enunciation of the Drk System.[22] Parameswaran is said to have evolved the Drk System as a result of his astronomical studies coupled with observations of celestial bodies for a period extending over 55 years. It is but natural that observations stretching over long periods are necessary for ascertaining minute differences in planetary motions and other celestial phenomena to enable one to draw valid deductions there from and enunciate new rules for calculation or offer corrections to existing schemes.

Parameswaran's '*Drigganita*' is strictly an astronomical manual giving the formulae and methods for the calculation of planetary positions.[23] This work is in two parts: the first part consisting of four sections, called paricchedas, pariccheda one is devoted to the derivation of the days elapsed in the kali epoch and the computation of the mean positions of the planets. Pariccheda two sets forth the positions of the mean planets at the commencement of the kali epoch to be used as corrections to the means as calculated by the methods given in pariccheda one. Computation of the true positions of the planets is dealt with in pariccheda three. The topics taken up in the last pariccheda are the derivation of the sine of the arc of anamoly and commutation (*Manda-jya* (*Jya* =sine) and *Sighra-jya*) and the method for the calculation of the arc from the sine.

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[22] S. Parameswaran, "Kerala's contributions to Mathematics and Astronomy", *loc.cit.*, p. 24.
[23] *Ibid.*, p. 25.

Part two of *Drigganita* contains, in its first half, a restatement in simpler language, using the easier Katapayādi notation of numerals of the main points enunciated in part one, and is intended for young learners. The second half of part II gives in full the tables of sines of arc of anamoly and commutation of the different planets. The author concludes the work with the enunciation of a method for the verification of the entries in the above tables of sines and a correction to be applied to the sun as derived in another work of his, the *Grahana-mandana*.

"The original contribution of *Drigganitam* lies not in the enunciation of any new methodology of working, but in the revision of the different astronomical constants, tables of sines etc. New multipliers and divisors are given for the derivation of the days in the kali epoch and for the calculation of the mean planets. The author has also indicated minute corrections to be applied to the means after long periods of time, which he specifies for each planet. Revised values are given for the mean positions of the planets at zero kali. The values of the higher apses of Mars and Jupiter have been revised. The values of the sines of anamoly and commutation for the different planets have also been revised. It may be noted that in place of division of the right angle into 24 parts of $3^{\circ}45'$ each, for laying down the sines, found in earlier works, Parameswaran has adopted a more convenient 15 part division of 6 degrees each.

After the advent of the new system, both the systems (the Drk and the *Parahita*) came to be used simultaneously. The Drk, being more accurate was used for *jātaka* (casting of horoscopes), *prasna* (horary astrology), *grahana* (prediction of eclipses) etc., while *Parahita*, being the orthodox system continued to be used for fixing *muhurtas* (auspicious moments for rituals and social ceremonies). Later on, however, the Drk System came to be used, by many, for all purposes". Parameswaran completed the writing of *Drigganita* in Saka 1353 (which corresponds to 1431 A.D.).[24]

Astronomers of Kerala during the medieval period

Kerala produced a number of astronomers during the medieval period and their works on astronomy, astrology and mathematics are valuable records. After the 12th century A.D., many works were written on astrology but few on astronomy and mathematics. The Indians began to look to the West for knowledge on these subjects. Some of the famous astronomers during the medieval period are mentioned here with their works.

Govindasvāmin (800-850)

Nilakantha Somayajin, the reputed astronomer of Kerala, gives in a *grahana* tract of his information that Sankaranārāyana was Govinda's pupil.

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[24] *Ibid.*, p. 26.

Sankaranārāyana was the court astronomer of King Ravivarma Kerala (Kulasekhara at Mahodayapuram). Govindasvāmin was one of the ablest exponents of Bhāskara I and of the Āryabhattan System[25] and considers Bhāskara's work as a *vrtti* on the Āryabhattiya.[26] His elaborate *Bhāsya* on the *Mahābhāskariya* contains new ideas and mathematical elaborations which remain to be fully recognized and expounded in terms of modern mathematics. An original work of his on astronomy and mathematics, which is under the title *Govindakrti* was quoted by writers like Sankaranārāyana, Nilakantha Somayaji and Narayana and his work on astrology is referred to by Nilakantha as *Govindapaddhati*. Manuscripts of his short commentary called *Prakatārtha* or *Sampradāyapradipika* on Parāsarahora were also known.[27]

Govindasvāmin's Mahābhāskriya Bhāsya

Govindasvāmin's *Bhāsya* forms an elaborate elucidation of the *Mahabhāskariya*. In Govinda's view the Bhāskariya is only an exposition of the Āryabhattiya and therefore he quotes and explains *āryās* and *gitikas* from the Āryabhattiya so fully that only a few verses therein have been left out. In addition to explaining the *Māhābhāskariya* text, Govinda gives also additional information which is his own, or reiterates what Bhāskara has

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25 T. S. Kuppanna Sastri and T. Chandrasekharan (ed.), *op.cit.*, p. XLVII.
26 K. Kunjunni Raja, Astronomy and Mathematics in Kerala, *op.cit.*, p. 127.
27 K. V. Sarma, Contributions to the Study of the Kerala School of Hindu Astronomy, *op.cit.*, p. 45.

said in his *Āryabhattiya-Bhasya*. Some of the more important topics which Govinda has dealt with in detail are the origin of the saka era, an extension of the methods given for the sun in the east-west or north-south directions to the corner directions as well. Correction for parallax for sunrise is discussed and the theory of planetary motions, Govinda gives more exact tabular sines and also methods to get the sines to a high degree of approximation, together with the inverse operation of finding the exact arc from the sines, the size and shape of the earth, sun and moon and the planets, the position of the earth in the solar system, the rotation of the earth and rising and setting of the sun, and the motion of planets in their orbits are discussed.[28]

Works of Govindasvāmin

Besides his *Mahābhāskariya Bhāsya*, Govindasvāmin has written at least three other works. A brief commentary called *Sampradāyadipika* or *Prakatartha* on Parasarahora is one. Nilakantha somayaji refers in the same *grahana* tract, to another astrological work of Govindaswāmin, the *Govindapaddhati.* Manuscripts of this work are yet to be unearthed. The title *Govindapaddhati* suggests that this might be an original work of the author.

[28] T. S. Kuppana Sastri and T. Chandrasekharan (ed.), *op.cit.*, p. XLIX.

Still another work of Govindasvāmin, which too is known only from quotations, is what is referred to as *Govindakrti*. Numerous quotations from this work occur in astronomical works of Sankaranārāyana, Nilakantha and Narayana. All these quotations are pertaining to mathematics and astronomy and it seems that this too is an original work of the author.[29]

Sankaranārāyana (825-900)

A new epoch in Kerala history dawned in the ninth century A.D. with the revival of Chera power under Kulasekharavarman which was followed by the reign of a galaxy of kings known as Kulasekharas of Mahodayapuram for about three centuries from A.D. 800 to 1102. The period marked an all pervasive transformation in the political, social and cultural fields. It was an age of great sages and seers like Sankaracharya, Kulasekhara Alwar and Cheraman Perumal Nayanar. The evolution of the Malayalam language as a distinct entity was a striking phenomena.[30]

Sthanu Ravi was one of the important rulers of the Chera dynasty who ruled from 844 to 855 A.D. An authority on astronomy, Sthanu Ravi extended his liberal patronage to the science. The reign of Sthanu Ravi was

29 *Ibid.*, pp. XLVIII – XLIX.
30 Adoor K. K. Ramachandran Nair (ed.), *Kerala state Gazetteer*, Vol. 2, part I, Trivandrum, 1986, p.169.

also one of economic prosperity.[31] The period of Sthanu Ravi became historically important for some other factors also. Sankaranārāyana, the famous astronomer who had written the commentary of '*Laghu Bhaskriya*' of Bhāskara, lived in Mahodayapuram (modern Kotungalloor near Cochin). During the period of Sthanu Ravi, Sankaranārāyana was accorded with royal patronage and was allowed to live in the palace of king. An observatory was established at Mahodayapuram under the direct supervision of the king.[32] It was known as Ravivarma Yantra Valayana where arrangements were made to notify the time for the information of the people by means of tolling of bells known as *kootu* at regular intervals of a *ghadika* (24 minutes).[33] It functioned in accordance with the principles laid down by Āryabhatta.[34]

Sankaranārāyana was the disciple of Govindasvāmin. He was a native of Kollapuri on the Arabian Coast. The only known work of his is a commentary on the Laghubhaskariya which he wrote in A.D. 869 known as *Sankaranarayaniyam*. Besides being highly elucidatory with regard to the subject treated there in, the work throws light on the keen interest evinced by the royalty in the promotion of the study of astronomy, the presence of an astronomical observatory at the capital city Mahodayapuram, the

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31 K. M. George (ed.), *The Malayalis*, New Delhi, 2002, p. 211.
32 T. K. Gangadharan, *op. cit.*, p. 101.
33 Kerala State Gazetteer, *op.cit.*, p. 175.
34 A. Sreedhara Menon, Social and Cultural History of Kerala, *op.cit.*, p. 294.

construction of buildings with due reference to mathematical principles, arrangements made in the city for announcing the times of the day- which all point to the conditions that greatly favoured the flowering of astronomical studies in that part of India[35] and is of great value in determining the chronology of the Chera emperor, Sthanu Ravi. It is made clear in this work that it was written in the twenty fifth regnal year of Sthanu Ravi.[36]

In his work Sankaranārāyana often refers to the Kerala King Ravivarma Kulasekhara who reigned at Mahodayapuram (Vanci) on the West Coast. Some of the examples in the work are questions posed by the King to the author; and in fact there are several passages in the work pointing to the interest taken by the King in astronomy. It is patent from these references that Sankaranārāyana was a resident of the above city and was a protégé of the above King. The fact that Govinda's pupil belonged to Kerala, coupled with the fact that his works are found and studied only in that part of the country, may lead us to suppose that Govindasvāmin too belonged to Kerala.[37]

According to the tradition recorded by Nilakantha, Sankaranārāyana had his residence at the capital city. He says that Govindasvāmin had not

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[35] K. V. Sarma, Contributions to the Study of the Kerala School of Hindu Astronomy, *op.cit.*, p. 45.
[36] K. M. George, *op.cit.*, p. 49.
[37] T. S. Kuppanna Sastri and T. Chandrasekharan (ed.), *op.cit.*, p. XLVIII.

made use of the Sakābda correction given by Haridatta and that after the death of Govindāsvamin, Sankaranārāyana made direct observations of a solar eclipse at Mahodayapuram and informed his patron about his findings as a result of which the Sakābda correction was popularized in Kerala. Both Govindasvāmin and Haridatta are praised in the beginning of the commentary. Speaking about the Saka era, Sankaranārāyana says: *evam śakābdāh punar iha candrarandhramuni* (791) *samkhyā asmābhir avagatāh.*

This Saka year 791 corresponds to A.D. 869, which may be taken as the date of composition of the work. The work also contains a reference to a total eclipse of the sun that took place in A.D. 866.[38]

There is also a reference to the fact that there was a conjunction of Jupiter and Saturn in Dhanu Rasi in the twenty fifth year after the accession of Sthanu Ravi to the throne. As this conjunction takes place only once in sixty years and this has been worked out scientifically as 869 A.D, the date of Sthanu Ravi's accession is rightly assigned to 844 A.D. It was the success in determining the date of accession of Sthanu Ravi that eventually helped to fix the date of the Tarisapalli Copper Plate granted in the fifth regnal year of this ruler as 849 A.D. Thus the *Samkaranarayaniyam* is of great help in determining the chronology of the Cheras of

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[38] K. Kunjunni Raja, Astronomy and Mathematics in Kerala, *op.cit.*, pp. 128-129.

Mahodayapuram.[39] With the passage of time and lack of interest taken by the successive rulers of Travancore, the observatory was neglected and diminished of its existence.

Period after Sankaranārāyana (A.D. 900-1200)

For about three centuries after Sankaranārāyana, the land Kerala does not seem to have produced any outstanding astronomer or mathematician. The scholars of the period were perhaps content with the preservation and transmission of the knowledge from generation to generation. But it was a period of active progress in the field in North India. Bhāskara II wrote in A.D. 1170 the *Siddhanta Śiromani,* a comprehensive work in four parts, namely Lilavati, Bijaganita, Grahaganita and Gola, which became popular through out India. Such works gave new impetus to the studies in Kerala, and from the thirteenth century onwards there has been an unbroken tradition for about five hundred years. The mathematicians of Kerala were staunch followers of the Āryabhattan School; but they understood the significance and limitations of Brahmagupta's theorems about the quadrilateral.

Besides Sankaranārāyana's *vivarana* there is another commentary on the Laghubhaskariya; this is the *Sundari* by Udayadivakara, manuscripts of which are preserved in Kerala, one of them dated A.D. 1644; from an

[39] A. Sreedhara Menon, *Kerala history and its makers*, Kottayam, 1987, p. 56.

ahargana (number of days elapsed from the beginning of the Kali era) mentioned in the commentary, it is known that it was composed in A.D. 1073. Nilakantha of Kelattur quotes from this work in his *Bhāsya* on the *Āryabhattiya.*[40] Hence it is quite possible that Udayadivakara also belonged to Kerala. He quotes several verses from one Jayadeva explaining the cyclic method of solving indeterminate equations of the type $Nx^2 + 1 = y^2$ usually attributed to Bhāskara II. Nothing further is known about Jayadeva.

Suryadevayajvan (A.D. 1191-1250)

Suryadevayajvan of Nidhruvagotra was a prolific writer recognized as an authority by later writers in Kerala like Parameswaran and Nilakantha. He gives a list of his earlier works in his commentary on the Laghumanasa; from this it is known that first he commented on Govindasvāmin's Bhāsya on the Mahābhāskariya; then he wrote the Bhataprakasa commentary on the *Āryabhattiya*; then a brief commentary on the *Māhāyātra* of Varāhamihira; afterwards he commented on the *Laghumanasa* of Munjālaka and on the *Jatakapaddhati* of Sripathi (the commentary is called *Jatakalamkara*). Parameswaran's commentary on the *Āryabhattiya* is based on Suryadeva's work; the *Jatakalamkara* is also quite popular in Kerala. From his name it is clear that he was a Somayajin.

40 *Ibid.*, p. 130.

He says that he was born on the *hasta* day of Kumbha month in the year Saka 1113 corresponding to A.D. 1191.[41]

Govinda Bhattatiri of Talakkulam (A.D. 1237-95)

Govinda Bhattatiri of Talakkulattur family belonged to the village of Alattur near Tirur in South Malabar well known in Kerala as Talakkulattu Bhattatiri and is renowned as the progenitor of the famous Pazhur kaniyar family of astrologers. A line of astronomical tradition which he started continued for more than 700 years.[42] His elaborate commentary on the first ten chapters of the *Brhajjataka* of Varāhamihira is known as *Dasadhyayi*. He says that it has been written to help students and not to show off his scholarship. The other work of Govinda is the *Muhurtaratna*[43] which has been commented on by Parameswaran, the grandson of Govinda's pupil.[44] He is said to have written also a *Muhurtapadavi*, which formed the basis for several later works of that name.[45] The members of the Kaniyar family of Palur, the famous astrologers of Kerala, trace their powers of prediction to the blessings of Govinda who is considered to be the progenitor of that family. From the way Parameswaran refers to him it is evident that Govinda

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41 *Ibid.*, pp. 131-132.
42 K. V. Sarma, Contributions to the Study of the Kerala School of Hindu Astronomy, *op.cit.*, p. 49.
43 Muhurtaratna, Manuscript Record, T. 63, Kerala University Oriental Manuscript Library, MSS.
44 K. Kunjunni Raja, Astronomy and Mathematics in Kerala, *op.cit.*, pp. 132-133.
45 Ulloor S. Parameswaran Aiyar, *Kerala Sahitya Charitram (Mal.)*, Trivandrum, 1990, p. 110.

was a very famous astrologer of his time. At the end of the *Dasadhyayi* he praises Lord Siva, the presiding deity of the temple at Triprannot.[46]

Madhava of Sangamagrama (A.D. 1340-1425): Madhava I

Madhava, referred to by later astronomers as Golavid (Master of spherics), was an astute mathematician who belonged to Sangamagrama, identified with Irinjalakkuda near Cochin. Madhava merits an abiding place among the great mathematicians not only of India but of the world. A number of Indian mathematicians e.g. Āryabhatta, Bhāskaras, Brahmagupta to mention only a few, had made significant contributions to astronomy, algebra, arithmetic and geometry, but it was Madhava who 'took the decisive step onwards from the finite procedures of ancient mathematics to treat their limit passage to infinity, which is the kernel of modern classical analysis.

Nilakantha Somayajin (1444-1545 A.D.) in his *Āryabhattiya Bhāsya* (commentary on *Āryabhatteyam* explicity mentions that Madhava was one of the teachers of Parameswaran (1360-1460 A.D.), the propounder of *Drigganita*.[47] Some scholars predict that Madhava belong to the Warriyar class of Thekkadethu family but it is not true. It is assumed that he is from Irinjapalli *illom* which is quite believable.[48]

46 K. Kunjunni Raja, Astronomy and Mathematics in Kerala, *op.cit.*, p. 133.
47 S. Parmeswaran, "Kerala's contributions to Mathematics and Astronomy", *loc.cit.*, pp. 185-186.
48 Ulloor S. Parameswaran Aiyar, *op.cit.*, p. 110.

Works

Among the works of Madhava now available *Venvaroha*[49] is considered as the most important. The moon's motion along its orbit round the earth is not uniform. This makes the computation of the position of the moon at some intermediate time during the course of the day, calculated on the basis of its true positions at sunrise or at sunset, inaccurate. An ingenious but facile method for the determination of the position of the moon at anytime of the day with high accuracy has been evolved by Madhava in *Venvaroha.*

The facile method enunciated by Madhava for the computation of the moon's location seems to have caught the attention of many astronomers who have extended the method further to yield still more precise results. Five works of this genre have been identified: namely *Candrasphutapi, Suksma Candrasphutanayanam, Venvaroha-kriya* (all of anonymous authorship) and *Venvarohastaka* of Putumana Somayaji (1660-1740 A.D.). But with the passage of time, *Venvaroha,* looks just like the old 'bow and arrow' before the modern intercontinental missiles.

Sphutacandrapti[50] is another work of Madhava dealing with the same topic discussed in the *Venvaroha*; but *Venvaroha* is a better organized

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49 Achutan, Venvaroha (vakyanam), Palmleaf, No. 10629-C, Kerala University Oriental Manuscript Library, MSS.

50 Sphutacandrapti, Palmleaf, No. 10856.E, Kerala University Oriental Manuscript Library, MSS.

work and incorporates most of the verses in *Sphutacandrapti,* often in an improved form. It seems likely that Madhava wrote *Sphutacandrapti* first and then improved it into *Venvaroha.* Thus *Venvaroha* (in 74 verses) is a revised and enlarged version of *Sphutacandrapti* (in fifty one verses). Madhava also revised the popular moon-mnemonics (*Candravakyas*) of Vararuci. Madhava is the author of *Lagnaprakarana* in six chapters; two tracts entitled *Madhyamanayanaprakara* and *Mahajyanayanaprakara* *Aganita* an extensive work on planetary computations along with an *Aganita pancanga* (an almanac) and *Aganitagrahacara.* Still another work possibly composed by Madhava is *Golavada*, which seems to have helped to stabilize his appellation as 'Golavid'.

Besides the afore said full fledged works, a number of stray aphorisms of Madhava are found as quotations in later astronomical and mathematical works like *Tantrasangraham*, Nilakantha's *Āryabhattiya Bhāsya*, *Kriyakramakari* (a sixteenth century Keralese commentary on Bhāskaracarya's *Lilavati*), *Yukti Bhasa*, *Karanapaddhati* etc. These verses are just the enunciations of certain mathematical results. Madhava has been hailed as the first mathematician to enunciate the trigonometrical formula: Sin (A ± B) = Sin A. Cos B ± Cos A. Sin B, known as 'jive Paraspara-nyaya' in the parlance of the Āryabhattan School[51] and is said to be the first

51 *Ibid.*, p. 188.

scholar to calculate correctly the value of II (relation between the circumference and the diameter of a circle) on the basis of an infinite series.[52]

Parameswaran of Vatasseri (A.D. 1360-1455): Parameswaran I

Among Indian astronomer-cum-mathematicians of the medieval period Parameswaran Namboothiri of Vatasseri, who flourished in the fourteenth to fifteenth centuries A.D. and produced over a score of works on astronomy (including mathematics) and astrology, deserves an honored place. He was a Rig Vedic Brahmin of the āsvalāyana-sutra and bhrigu-gotra and belonged to the village of Ālattur in South Malabar, Kerala. His house, known as Vatasseri *illom* was situated on the northern bank of the river Nila or Bharatapuzha, where it joins the Arabian Sea, a fact mentioned in several of his works.

'Nilābdhyoh sangamāt saumye sthitena',

'Nilāyah saumyatire bdheh kulasthah Parameswarah'.

Details regarding Parameswaran's parents are not available. Parameswaran's grand father was a pupil of the famous astrologer Govinda Bhattatiri of Talakkulam (A.D. 1237-95) who had started a line of astronomical tradition which continued for more than 700 years.[53] This

52 K. Kunjunni Raja, Astronomy and Mathematics in Kerala, *op.cit.*, p. 135.
53 S. Parameswaran, "Kerala's contributions to Mathematics and Astronomy", *loc.cit.*, pp. 23-24.

Govinda is different from the author of the *Mahābhāskariya* who lived much earlier.[54]

Parameswaran refers to one of his teachers, named Rudra (A.D. 1325-1400) in several of his works. Nilakantha Somayajin, who was a student of both Parameswaran and his son Damodaran, mentions about two other persons who taught Parameswaran, viz., Narayanan and Madhava. Of these two teachers no information about Narayanan, other than that his father's name was Parameswaran, is available while Madhava can be identified with the great mathematician-cum-astronomer, Madhava of Sangamagramam.[55]

In his younger days Parameswaran, imbibed well, the rationale of mathematical and spherical astronomy from astronomers like Rudra, Narayana, son of (another) Parameswaran, and Madhava (of Sangamagrama). He identified the differences between observed (planetary) positions and those derived from the computational methods (taught by earlier authorities) and understood the cause of the differences. He thought over the enunciations found in several texts, verified them with the eclipses and planetary conjunctions and from a consideration of all matters, composed his *Drigganita.*

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54 K. Kunjunnni Raja, Astronomy and Mathematics in Kerala, *op.cit.*, p. 138.
55 S. Parameswaran, "Kerala's contributions to Mathematics and Astronomy", *loc.cit.*, pp. 23-24.

It would be highly instructive to know how Parameswaran, who promulgated the *Drigganita* System of astronomy in Kerala, strove to perfect his system by astronomical observations. He is reputed as a sky watcher, scanning the sky and recording astronomical phenomena continuously for a number of years.

Nilakantha Somayajin, who imbibed astronomy from Parameswaran states that Parameswaran composed the *Drigganita* (A.D. 1430) on the basis of his astronomical observations for fifty years before writing the *Drigganita*.[56]

Scientific outlook of the Author

In his writings Parameswaran reveals a scientific outlook which is remarkable in the case of a medieval writer.[57] He has averred in the beginning of the *Grahanamandana*, the ornament of eclipses that he was setting out to compose the present work after watching the movements and positions of planets on numerous occasions.

"Drstvā golasya samsthitim bahuśah" sloka. 3[58]

Then again, in the beginning of his *Drigganita* he has made a similar statement. This experimenter, thinker and practical astronomer of high

56 K. V. Sarma *"Āryabhatta and Āryabattan Astronomy Antecedents, Status and Development"*, International seminar on Āryabhatteyam, Thriuvananthapuram, January 12-16, 2000, p. 13.

57 Grahanamandana and Grahanastakam, T. 179 a and b, Kerala University Oriental Manuscript Library, p. 12, MSS.

58 Ibid., sl. 3, p. 1.

caliber pronounces the following judgement on the accuracy of the results arrived at through the computations enunciated by him in his *Grahanamandana* which is a work of elaborate and painstaking labour:

"Kāloanena ca sidhah Kadācidayi phidyate swalpam".[59]

He goes on to quote, disapproving Varāhamihira in this matter. Varāhamihira has stated in his *Brhatsamhita,* verse 25, that he had given the predictions for the effects of eclipses which occur outside their calculated times only to be in conformity with ancient authors, implying thereby that he does not believe that an eclipse could ever happen like that. The observer and experimenter, par excellence, that Parameswaran is, he realizes the limitations of Varāhamihira's calculations, as also of those evolved up to his own time and also by himself, and so shrewdly suggests that the small differences observed at times must be due to factors that had not been taken into account or were not known to them. But, as a practical scientist and as one who had been able to enunciate many a correction, he is confident that it would be possible to postulate, as a result of further observation and experimentation, the necessary corrections by the application of which even the small differences found to occur at times could be eliminated.[60]

Some light on the author's methodology, prolonged observation, experimentation, recording of the readings, tallying of the values obtained

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59 Ibid., sl. 96, p. 12.
60 K. V. Sarma (ed.), *Grahanamandana of Parameswaran*, Hoshiarpur, 1965, pp. x-xi.

by observation with those got through calculation and the postulation of samskara (corrections) to make computation accord with observation, is thrown by a long discursion he gives, at the close of his commentary *Siddhāntadipikā* on the *Mahabhāskariya Bhāsya.* This discursion seems to have also an independent entity by itself since this is found inscribed in as a separate piece.

The author commences this digression with the statement that he had been observing eclipses from Saka 1315, that he had found that the observed times always preceded the computed times, and that this, obviously, showed the need for corrections.[61]

He goes on to enunciate different astronomical concepts and process of calculation in the computation of eclipses and the various corrections to be applied at the different stages of computation. The appearances to the naked eye of eclipses at their commencement and end of eclipses of very limited extent are also noticed. The author, then, refers, with the recording of the exact date and place, a number of eclipses he had observed.[62]

He then enunciates the true positions of the sun, moon, moon's higher apsis and node at sunrise for a particular contemporary date, as calculated with the application of the corrections he had proposed, so as to form the zero-corrections for calculations beginning from that date and

61 Grahana-Nyaya-Dipika, sl. 1, 2, 3, 762 (G), Kerala University Oriental Manuscript Library, MSS.
62 Ibid., sl. 86, 87.

suggests that similar verification should be made and further corrections postulated and applied in course of time, as and when necessary.[63]

Works of Parameswaran

Parameswaran was a prolific writer, author of original works and commentaries covering all fields of Jyothisha,[64] was an eminent mathematician and astronomer of his day. He lived in Kerala where the *Parahita* System of astronomy was prevalent. By improving upon that system, he ushered in the new Drk System of his own.[65]

His works on astronomy are:

1. *Drigganita*, the author's magnum opus, is strictly an astronomical manual giving the formulae and methods for the calculation of planetary positions[66] and presenting the fundamentals of his revision of the *Parahita* System of astronomy.[67]

2. *Goladipika* (I), on spherical geometry and astronomy.

3. *Goladipika* (II), in four chapters, on the same subject as above, but different from it, hardly ten verses being common between the two.[68]

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63 Ibid., sl. 91, 93.
64 K. V. Sarma (ed.), *Grahana-Nyaya-Dipika of Parameswaran*, Hoshiarpur, 1966, p. xiv.
65 *Ibid.*, p. xviii.
66 S. Parameswaran, "Kerala's contributions to Mathematics and Astronomy", *loc.cit.*, p. 25.
67 T. S. Kuppanna Sastri and T. Chandrasekharan (ed.), *op.cit.*, p. LII.
68 K. V. Sarma (ed.), Grahanamandana of Parameswaran, *op.cit.*, p. xiv.

At the end of the *Goladipika* Parameśwaran gives the latitude and longitude of the place of his birth:

It was eighteen yojanas to the west of the Ujjain meridian and had a sine latitude 647 or 10°51" north latitude.[69]

4. *Grahanamandana* or the ornament of eclipses is an important astronomical work dealing with the accurate computation of the solar and lunar eclipses.[70] The *Grahanamandana* exists in two versions, one of 89 slokas and the other of 100 slokas (actually of 91 and 102 slokas, respectively, when the introductory and concluding verses are also taken into account).[71] The text belongs to the Karana[72] type of astronomical works, and, as such, the calculations are commenced in this work from a recent zero date, arrived at by deducting from the current Kali date a large chunk (*khanda*) of 16,48,157 Kali days, which corresponds to the Kali year 4512, *kataka* 17 or A. D. 1410, July 15.[73] The mean positions of the sun, moon, higher apsis (*pālā*) and ascending node (*Tunga*), which are required for the computation of eclipses, have been accurately calculated by the author for the above *khanda* and given as the zero corrections or additive constants

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69 K. Kunjunni Raja, Astronomy and Mathematics in Kerala, *op.cit.*, p. 137.
70 K. V. Sarma (ed.), Grahanamandana of Parameswaran, *op.cit.*, Forward page.
71 *Ibid.*, p.xvii.
72 The word 'Karanam' means a mode of computations or a work on the same and a manual on. Astronomical calculations based on a particular time or date is called a Karana.
73 Grahanamandana and Grahanastakam, sloka. 5, p. 1.

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(*dhruva-s*)[74] to be applied to their mean positions as calculated from the zero date.[75] The further *slokas* enunciate the different corrections to be applied to the mean positions and, thus, arrive at their correct positions at the syzygies (*parva-s*), the full moon or new moon, as the case may be.[76] The method to check the possibility of eclipses on the *parva* days is also given, since further work might be done only in the case of those parva-*s* where eclipses are possible.[77]

The calculation of the orbital diameters of the sun, moon and the earth's shadow is enunciated next.[78] The methods for the actual computation of the eclipses of the moon and the sun, and the special work applicable only to the solar eclipse take up the major part of the rest of the work.[79]

5. *Grahananyayadipika*, the theory of eclipses is an important work in Sanskrit explaining the rationale of the lunar and solar eclipses according to ancient Indian astronomy. The *Grahananyayadipika* has been composed, as stated by the author,[80] for explaining the rationale of the theory of eclipses of which the methods of computation had been set out by him already in some of his other

74 Ibid., sloka 9-12, p. 1.
75 Ibid., sloka 5-8, p. 1.
76 Ibid., sloka 13-30, p. 2-3.
77 Ibid., sloka 30-31, p. 3.
78 Ibid., sloka 31-35, p. 3.
79 Ibid., sloka 37-72, pp. 4-5.
80 Grahana-Nyayadipika, slokas 5, 85

works like the *Grahanamandana* and the *Grahanāstaka,* and as such, the work *Grahana nyayadipika* is a sequel to those earlier works. It is, however, self contained, giving as it does, the astronomical constants necessary for eclipse computation and the indication of the methods therefore. The different astronomical concepts like the Madhyalagna, Drkksepalagna, Madhyahnajyā, Drkksepasanku, Drggatijya, Nati and Lambana are expostulated in the order in which they are required in the computation of eclipses. The *Grahanavidhi* is explained in great detail.[81] The *valanas*, viz., *Āksa* and *Āyana* and the calculation there from, of, the *Sphutavalana* are treated next.[82] *Anādesyagrahana* or eclipses of limited duration and extent which would not be visible to the naked eye and, so, are not to be predicted in almanacs etc., are indicated in sloka 80[12] and the *Udayāntara Samskara* or correction for reduction to the equator to be applied to the predicted time in sloka 81-83. Directions for *Grahana-lekhana* are given in detail in slokas 73-77. This is of special interest, since the progress of an eclipse can be charted on the eclipse diagram and the extent of the eclipse at any desired moment known from the graph.[83]

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81 Ibid., slokas 41-63.
82 Ibid., slokas 65-72.
83 K. V. Sarma (ed.), Grahana-Nyaya-Dipika of Parameswaran, *op.cit.*, Forward page.

6. *Grahanāstaka,* an eclipse, in 10 verses. These three works, viz., *Grahanāstaka*, *Grahanamandana* and *Grahananyayadipika* are the works on improved computation and rationale of eclipses. *Grahanāstaka* is a succinct manual on the calculation of eclipses. Since much matter had to be compressed into eight verses, the work is necessarily terse. It should also be noted that the object of the author is primarily to enunciate certain principles in the calculations and to give revised measurements and tables as contrasted with the older system which it takes for granted. It does not, therefore, treat of the processes of calculation exhaustively nor in their sequential order; this the author does in the *Grahanamandana*.[84]

7. *Vākya Karana,* on the methods for the derivation of the several astronomical tables.[85] Several of the standard works on astronomy and mathematics which were popular in Kerala have been commented upon by Parameswaran.

8. *Bhatadipika*-This is a succinct commentary on the *Āryabhattiyam*, as has been mentioned by the commentator himself (*Vyākhyālpā Kriyate Mayā*). Though succinct, this commentary throws much light on passages which appear difficult to the reader.[86]

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84 S. Parameswaran, "Kerala's contributions to Mathematics and Astronomy", *loc.cit.,* p. 30.
85 K. V. Sarma (ed.), Grahanamandanam, *op.cit.,* p. xv.
86 S. Parameswaran, "Kerala's contributions to Mathematics and Astronomy", *loc.cit.,* p. 30.

9. Parameswaran on the *Laghubhaskariya* of Bhāskara I.

10. *Karmadipika* on the *Mahabhaskariya* of Bhāskara I.

11. The *Siddhantadipika* of Parameswaran edited here though expressedly a commentary on Govindasvamin's *Bhāsya* on the *Mahabhaskariya*, is often more than that and takes up the role of the *Bhāsya* itself where the latter is sparse, and comments on the original text itself. Besides, in several places it gives original ideas and methods of its own, in great detail, mostly in metrical form.

It elaborates the principle and method of reduction of fractions used in the solution of indeterminate equations. The *Siddhantadipika* gives its own method of finding the *Mati*, it quotes an alternate method to solve equations of the type called Sagra-Kuttakara. It gives an alternative interpretation as given by "certain astronomers" (*anye punah*), and an amplification of the process of getting the interval between the sun on the prime vertical and the mid day, in 24 verses. For the *Bhāsya*, the commentary gives an alternate method in 11 slokas. Under the same verse it gives also a method to solve problems with the sun at the intermediate directions, alternative to what is given in the *Bhāsya*, and also extending it to the sun in any direction, it explains the principle involved in the method of drawing a circle passing through three points. There is a long discursion in 68

slokas giving an alternate method to obtain exact sines and arcs, the opinion of certain astronomers in the matter of making the correction for the equation of the centre and for the equation of conjunction; and after that he gives instructions for graphical representation of the ex-centric and epicyclical methods in 32 stanzas, on the theory of eclipses with a detailed description of Parameswaran's own observations of several solar and lunar eclipses from which important astronomical data can be derived and it shows an awareness of the error in the method given in the text for computing the latitudes of the star-planets.

Besides these valuable additions and corrections, the *Siddhantadipika* discusses alternative readings both of the text and the *Bhāsya*.[87]

12. Parameswaran on the *Laghumanasa* of Munjala.
13. *Vivarana*, on the *Surya Siddhanta*
14. *Vivarana*, on the Lilavati of Bhāskara II
15. *Vrtti*, in verse, on an anonymous *Vaytipatastaka*, a work on the calculation of the astronomical phenomena called *Lata* and *Vaidhrta.*
16. *Vrtti* on his own *Goladipika* (II)

[87] T. S. Kuppanna Sastri and T. Chandrasekharan (ed.), *op.cit.*, pp. LIII-LIX.

Primarily an author of astronomical works, Parameswaran has written also on astrology. His works in this field are:

17. *Acarasangraha*, a popular work, of which many manuscripts are known to exist in South Indian collections.

18. *Jatakapaddhati*, on horoscopy.

19. Commentaries on

    (i) The *Muhurtaratna* of Govinda

    (ii) The *Jatakadesa* of Sripati

    (iii) The *Prasnasat pancasika* of Prthuyasas

20-22 Muhurtastaka-dipika, Vakyadipika and Bhadipika, which Parameswaran mentions along with some other works of his at the end of his commentary on the *Mahābhāskariya* are yet to be recovered.[88]

Damodara of Vatasseri (A.D. 1410-1510): Damodara I

Of Damodara, son of Parameswaran of Vatasseri, no full fledged work is known, but his pupil Nilakantha Somayaji refers to him as an erudite astronomer.[89] Damodara is the regular teacher of Nilakantha who initiated him into the science of astronomy and instructed him on the various principles underlying mathematical calculations. He was the

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[88] K. V. Sarma (ed.), Grahanamandanam, *op.cit.*, pp. xv-xvi.

[89] K. V. Sarma, Contributions to the Study of the Kerala School of Hindu Astronomy, *op.cit.*, p. 54.

resident of the village of Alattur (Sanskritised into Asvatthagrama) which was situated quite near Nilakantha's own village, Trkkantiyur.[90]

Astrological work *Muhurtabharana*[91] is sometimes attributed to this Damodara. But it has been shown that this ascription is wrong since it is clear from the introductory verses of this work that this Damodara was the son of Kesava of the Bharadvaja gotra, while Damodara I is the son of Parameswaran of the Bhargava gotra.[92]

Nilakantha Somayaji (A.D. 1444-1545): Nilakantha I

Nilakantha Somayaji, the centenarian astronomer hailed from Tr-k-kantiyur (Mal.) (Sanskritised into Kundapura or Kundagrama), near Tirur, Ponani taluk, South Malabar, a famous seat of learning in Kerala during the Middle Ages. The name of his illom is Kelallur (sometimes spelt also as Kerallur). It is sanskritised into Kerala-sad-grama corresponding to the Malayalam word Kerala-nal-l-ur.[93] He was a Namboothiri of the Garga-gotra and therefore he is often referred to as Gargya Kerala Nilakantha or Gargya Kerala Sadgrama Nilakantha. He was a Bhatta following the Āsvalāyanasutra of the Rig Veda, and became a Somayajin (or comatiri as it is called in Malayalam) by performing the soma sacrifice. His father was

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90 K. V. Sarma, "Āryabhatta and Āryabhattan Astronomy Antecedents, Status and Development", *op.cit.*, p. 116.
91 Muhurtabharana, Manuscript Record, T. 71, Kerala University Oriental Manuscript Library, MSS.
92 K. V. Sarma (ed.), *Golasara of Gargya-Kerala Nilakantha Somayaji*, Hoshiarpur, 1970, p. xvi.
93 *Ibid.*, p. xii.

Jatavedas; he had an uncle also named Jatavedas.[94] Nilakantha refers to his younger brother Sankara in several places in the Āryabhattiya Bhāsya. Sankara too seems to have been well versed in astronomy and followed his elder brother's studies. Nilakantha observes at the close of his *Bhāsya* on the Golapāda that he was entrusting the *Bhāsya* to Sankara for its proper propagation.[95] He is referred to as a 'living' authority by Madhava of Īñcakkāzhvā in his Prasnasara, composed in 1542-43. He and his brother Sankara were patronized by Kausitaki Adhya Netranarayana (Āzhvāñceri Tamprākkal), the hereditary religious head of the Namboothiris.[96] It is also clear that the patron had great esteem for Nilakantha's erudition in astronomy, in which subject he too was interested and used to discuss intricate points with Nilakantha. It is clear from this that the credit of enthusing Nilakantha in his investigations, and, in fact, to have prompted him to write his *Bhāsya*, goes to Netranarayana, the members of whose family are known all through the annals of Kerala history to have been good scholars and at the same time munificent patrons of scholarship.[97]

Damodara, son of Parameswaran, of Vatasseri family in Alattur was Nilakantha's main teacher in mathematics and astronomy. Nilakantha says that as a boy he stayed in his teacher's house for several years and was engaged in studies. This was in accordance with the system of education

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94 K. Kunjunni Raja, Astronomy and Mathematics in Kerala, *op.cit.*, p. 144.
95 K. V. Sarma (ed.), Golasara of Gargya-Kerala Nilakantha Somayaji, *op.cit.*, p. xiii.
96 K. V. Sarma, Contributions to the Study of the Kerala School of Hindu Astronomy, *op.cit.*, p. 56.
97 K. V. Sarma (ed.), Golasara of Gargya-Kerala Nilakantha Somayaji, *op.cit.*, pp. xiv-xv.

prevalent in Kerala till the introduction of the modern school system. The great astronomer Parameswaran was perhaps still alive when Nilakantha went to his teacher's house; and naturally the young boy might have received some instructions on certain points from him. Nilakantha often refers to Parameswaran as his Paramaguru and considers him as a great authority. Another teacher of Nilakantha was Ravi from whom he learnt Vedanta. Nilakantha was also a good student of the Sastra-s; Sundararaja, a Tamil astronomer who was his younger contemporary, refers to him as a scholar in the six darsana-s; and in his *Bhāsya* Nilakantha himself quotes from sastra works like *Parthasarathi-misra's Vyaptinirnaya* and *Bhartrhari's Vakyapadiya*. Besides these Nilakantha travelled throughout Kerala collecting material from various scholars outside Kerala as is clear from his *Sundararajaprasnottara* clarifying doubts raised by Sundararaja, an astronomer from TamilNadu. Nilakantha was a devotee of Siva, the deity of the temple at Triprannot (sanskritised as Svetaranya) not far from his village of Trikkantiyur.[98]

Works of Nilakantha

Nilakantha has written several works which reflect his deep study and ripe scholarship in astronomy, embodying the result of his

[98] K. Kunjunni Raja, Astronomy and Mathematics in Kerala, *op.cit.*, pp. 145-146.

investigations in the subject and interpreting the science lucidly. A mention of his works may be made here.

1. The *Golasara* in three paricchedas is a short work that is the quintessence of spherical astronomy in fifty six arya verses. The first pariccheda sets out the basic astronomical constants, viz., the number of civil days and the revolutions of the planets in an aeon, the positions of the higher apsis and the ascending nodes of the planets, their maximum latitude, their epicycles to the equations of the apsis and of conjunction, the diameters of the orbits of the sun and the moon and the yojana measures of the epicycles.

   Pariccheda II is concerned with the presentation of the celestial globe (*jyotir gola*) from the point of view of astronomical conceptions and observations and the movement, therein of the heavenly bodies. The position of the great circles, *Ghatika-mandala* and the *Apakramamandala*, their mutual obliquity, the division of the ecliptic, the (apparent) rotation of the celestial globe, the rising point of the ecliptic (*lagna*), the measure of the orbits of the planets, the measurement of the positions of the planets on the ecliptic and the position of the horizon (*unmandala*) at the equator and elsewhere are noticed here, in order.

In Pariccheda III, 1 to 15 deals with the circle and the graphical and computational derivation of the sines. Verses 16 to 30 discuss the inter relationship of the manda, sighra and kaksya circles of the different planets and also how the results arrived at by calculation of the positions of the planets are affected by their ksepa (deflection) from the ecliptic.[99]

2. *Siddhantadarpana*, a short work in thirty two anustubs, indicating the astronomical constants with reference to the kalpa and specifying his views on the main astronomical conceptions and topics on which there are differences of opinion among authorities.

3. *Candracchayaganita*, or merely *Chayaganita* under which title it is generally cited, a short work in thirty one verses on the methods for the calculation of the moon's shadow and of the time during night on the basis of the shadow.

4. A commentary on the *Candracchayaganita* above, elucidating clearly the principles and methods enunciated by him in the text.

5. *Tantrasangraha*[100] divided into eight chapters comprising of 432 verses. This is a major work of Nilakantha and is an erudite treatise on astronomy. As a work belonging to the Tantra class, it takes the

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[99] K. V. Sarma (ed.), Golasara of Gargya-Kerala Nilakantha Somayayi, *op. cit.*, pp. vii-viii.
[100] Tantrasangraha, Palmleaf, No. 8380, Kerala University Oriental Manuscript Library, MSS.

commencement of the *yuga* as the starting point for calculations. In the several chapters it deals with:

i. Astronomical constants and general principles and conceptions.

ii. Calculation of the geocentric positions of the planets.

iii. The gnomon and calculations there with

iv. Eclipses of the moon and the sun

v. Specialties in the sun's eclipse

vi. Vyatipata

vii. The phases of the moon etc.

viii. Sṛṅgonnati of the moon.

It may be specially noted that unlike some scholars of Kerala who treat both the *Parahita* and Drk Systems in their works, Nilakantha treats here only of the Drk System, of which he was a great protagonist.[101]

Two commentaries on this work are known: the *Laghuvivrti* by Sankara Variyar of Trikkutaveli written at the instance of Āzhvāñceri Tamprākkal, and another by a student of Jyesthadeva.[102]

6. *Āryabhattiya Bhāsya*, an elaborate commentary on the cryptic and sutra like text of Āryabhatta which comprehends in 121 *aryas* the

[101] K. V. Sarma (ed.), Golasara of Gargya-Kerala Nilakantha Somayayi, *op.cit.*
[102] K. Kunjunni Raja, Astronomy and Mathematics in Kerala, *op.cit.*, p. 151.

fields of mathematics and astronomy. The lucid manner in which the difficult conceptions about the celestial globe and astronomical calculations are made clear, the wealth of quotations and the results of personal investigations and comparative study presented therein amply justify the appellation 'Mahabhasya' which Nilakantha gives to his work.

Nilakantha has commented only on the Ganita, Kalakriya and Golapadas of the Āryabhattiya, leaving out the Gitikapada, which he says is covered by the commentary on the other three sections.[103]

On the various commentaries available on *Āryabhatteyam*, *Āryabhatteeyam Bhāsya*, the one by Nilakantha Somayaji is unique for the following reasons:

a. The author clearly lays down the basic principles, essential for proper understanding of the science of astronomy in proper perspective.

b. He gives a graphic description of the motion of celestial objects, their shapes, their orbits, which would be useful in comprehending the subject.

c. To substantiate a particular point the author extensively gives quotations from other astronomical works available at his

[103] K. V. Sarma (ed.), Golasara of Gargya-Kerala Nilakantha Somayayi, *op.cit.*, pp. xviii-xix.

time of composition, which would enable the readers to digest the subject better and also know how others have viewed and described the same phenomenon.

d. As an erudite scholar in other branches of knowledge like Vedanta, Meemamsa, etc., Nilakantha aptly quotes the principles and methodologies used in those branches, and bring out their relevance in the field of astronomy too.

e. Most importantly, if there were discrepancies between two schools of thought, Nilakantha discusses the issues thoroughly and points out the flow in the most dignified manner without coming down heavily or crudely dismissing one view point and blindly upholding the other.

f. There is a remarkable degree of openness, which is a general characteristic of Indian science all through history.[104]

7. *Siddhantadarpana-Vyakhya*, a commentary by Nilakantha on his own *Siddhantadarpana*. The commentary is elaborate and resembles, in diction and treatment, his *Āryabhattiya Bhāsya*. It is in this work that Nilakantha gives the actual date of his birth.

[104] K. Rama Subramanian, "*Āryabhatteeyam – in the Light of Āryabhatteeyam-Bhasya by Nilakantha Somayaji*, International seminar on Aryabhatteyam, p. 116.

8. *Grahananirnaya*, a work on the computation of lunar and solar eclipses, possibly a short text in verse, like his other shorter works.

9. *Sundararajaprasnottara-* Sundararaja, son of Anantanarayana was an astronomer of the Tamil country contemporaneous with Nilakantha and author of a detailed commentary on *Vakyakarana* or *Vakyapancadhyayi* which is the basic manual on which almanacs in the Tamil districts are computed. Sundararaja had the greatest respect for Nilakantha whom he addressed for clarification of certain points in astronomy. Nilakantha's detailed answers to these questions formed a regular work, *Sundararajaprasnottara*.

10. *Grahana-grantha*, written in continuation of Nilakantha's *Siddhantadarpana-Vyakhya*. It goes on to describe the necessity of correcting old astronomical constants by observation, deals in detail with the Sakabda-Samskara, quotes the verses of his paramaguru Parameswaran from his *Siddhantadipika* (*Mahābhāskariya- Bhāsya –Vyakhya*) on the latter's observation of some eclipses, and after some more discussions ends abruptly.[105]

11. It was given to Nilakantha to produce a unique work entitled *Jyotirmimamsa* (investigations on Astronomy), solely devoted to discussions on astronomical theories, apparent inconsistencies

[105] K. V. Sarma (ed.), Golasara of Gargya-Kerala Nilakantha Somayayi, *op.cit.*, pp. xix-xx.

between computed and observed results, and enunciation of corrections. He makes some instructive statements on observational astronomy as well. The methodology of astronomical revision adopted by Nilakantha, by observation and experimentation, is unexceptional.

'The correlation of the computed moon etc. with actual observation at a particular place, the revision of computation on the basis of such correlation, logical inference there from being transmitted as tradition, its being again corrected (through observation and again revised) and transmitted further down to others… this is how tradition is continued without interruption. And this gives continued authoritativeness to tradition'.

In the light of these and of eclipses actually observed by the experimenter, future eclipses should be computed and forecast or, eclipses occurring at other parts of the country should be computed using the longitude, latitude etc. of that part of the country and, with that as the basis, the true sun, moon, apsis and node (at the relevant times) ascertained. Then, from the sun, moon, apsis and node as ascertained as above, past and future eclipses at one's place shall be computed, using the latitude and longitude of one's own place.

The uniqueness of the work *Jyotirmimamsa* and its importance in providing a picture of the practical and observational astronomy during medieval times in Kerala would be clear from the above. The picture would have been full had alone the instruments used by these enterprising astronomers and the manner in which they used them and recorded the observations over long periods of time were available. The instruments, constructed out of perishable material, seem to have been lost in the ravages of time and the palm leaves on which rough recordings had been made seem to have been discarded.[106]

Sankara of Kelallur (A.D. 1475-1575): Sankara I

Nilakantha Somayaji's younger brother Sankara, an astronomer in his own right, was, like his brother, patronized by the Azhvāñceri Tamprākkal, at whose house he was teaching astronomy as mentioned in Nilakantha's *Āryabhattiya-Bhāsya*. The said *Bhāsya* had been composed for the sake of Sankara, who was also entrusted with its propagation.[107]

Period after Nilakantha

The period following Parameswaran's *Drigganita* and Nilakantha's *Āryabhattiya Bhāsya* was one of great enthusiasm and brisk activity in the

[106] K. V. Sarma, *Observational Astronomy in India*, University of Calicut, 1990, pp. 49-52.
[107] K. V. Sarma, Contributions to the Study of the Kerala School of Hindu Astronomy, *op.cit.*, p. 57.

field of astronomy and mathematics. The *Tantra Samgraha* contained in a brief form all the results of the latest work on the subject. The discussions, verifications and proofs are to be found in the commentaries in Malayalam and Sanskrit of the *Tantra Samgraha* and works based on these. Nilakantha lived for a long time and many of the scholars were his direct or indirect students. Jyesthadeva, author of the *Yuktibhasa*; Sankara Variyar author of the *Laghuvivrti* on the *Tantra Samgraha* and the *Kriyakramakari* on the *Lilavati*; and Citrabhanu, author of the *Karanāmrtam*, are some of the scholars of the time. The Tamprākkal of Azhvāñceri of that time took a great interest in such studies and encouraged scholars.

Before dealing with the major writers of this period, the names of some of the less known works may be mentioned here. The *Karanasara*, which in four chapters discusses the calculations according to the *Drigganita* System, was written by a student of Nilakantha and Damodara in the sixteenth century. A Malayalam commentary on this work by Sankara, probably of *Mahisamangalam*, is also known. There is another similar work, the *Tantrasara* by one Narayana of Perumanam village, with the anonymous Malayalam commentary.[108]

[108] K. Kunjunni Raja, Astronomy and Mathematics in Kerala, *op.cit.*, pp. 152-153.

Citrabhanu (A.D. 1475-1550)

Among the immediate followers of Nilakantha was Citrabhanu Namboothiri, author of the manual on astronomical computation in four chapters, was a pupil of Nilakantha Somayaji. He belonged to the Gautama gotra and hailed from the village of Covvaram (Skt. Sivapuram) near Trichur. The date of composition of *Karanāmrtam* which is indicated in that work by the *Kalichronogram Buddhyon Mathyoddhrtam Yatnāt* (16, 91,513) (A.D. 1530) gives the clue to its author's date.[109]

The work *Karanāmrtam* is a short treatise intended for the practical use of the astrologers and the almanac makers, written in the year 1530 A.D. by Citrabhanu of Kerala. Particularly noteworthy is the method of dating time followed in this astronomical manual.

Citrabhanu the author of *Karanāmrtam* gives in the first chapter the absolute minimum of formulae, tables, constants, derivations of the mean and true positions of the nine planets-*Navgraha*, the essential requirements for making the Kerala calendar, in forty five stanzas of the text and their commentary. He is not at all bothered about the rationale of any of the mathematical processes enunciated, nor does he entertained any doubt or

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[109] K. V. Sarma, Contributions to the Study of the Kerala School of Hindu Astronomy, *op.cit.*, p. 57.

differences of opinions concerning the correctness of the astronomic principles accepted or of the mathematical operations formulated.

The second chapter consisting of only twenty six stanzas is a display of the author's knowledge of ancient Indian geometry. The instruments made use of are only the gnomon and the gnomonic shadow.

The mode of fixing the four quarterly directions of a particular locality making use of the gnomonic shadow presented in this chapter is strikingly quite modern. The circle drawn with the gnomonic shadow as radius at any time is considered to be a miniature circle concentric to the rational horizon, which divides the globe into two equal parts. Sun's diurnal circle is taken to be always parallel to the ecliptic, the great celestial circle surrounding the globe and passing through the two opposite points east and west. That all these, the horizontal circles, rational, visible or parallel, or concentric and all the meridional circles passing through the zenith and the nadir should necessarily pass through the two poles of the ecliptic circle, is an important proposition in advanced geometry. But the assumption though it is perfectly true, that all parallel lines meet at infinity and that all parallel tangents, chords, diameters etc. of all the circles concentric to the horizontal should necessarily pass through the true north and south poles of the

ecliptic, is generally found only in modern Geodesy[110] and higher mathematics.

Citrabhanu in two or three simple couplets graphically narrates how to determine the four cardinal directions. Take a convenient measure of the hypotenuse (in *angulas*) of the right angled triangle formed by the twelve angulas (gnomon) and calculate the base by the formula, ^{2}shadow = $\sqrt{gnomon^2 + base^2}$ with this shadow as radius draw a circle and place the gnomon in the centre. Also prepare two thin smooth sticks, one measuring double the gnomon and the other double the base. When the sun's shadow just touches the circumference, mark that point. If the two sticks are now set at right angles at this point and within the circle, the stick measuring double the gnomon would be in the east-west line and the other in the north-south direction.

The up to date way of determining the latitude and longitude of a place is by the observation of the pole star through a telescope in the observatories. Actually the pole star is revolving round the north pole in a small diurnal circle of 6½ minutes radius and is crossing the meridian twice daily, once above and then beneath the pole in steady and equal intervals of time. By mounting the telescope towards the pole star for two or three days consecutively, these meridional transits of the pole star are

[110] Geodesy: The science of measuring the earth and its surface or surveying on a large scale.

caught exactly on the equator of the telescope and the precise north-south direction is finalized.

All computations regarding solar and lunar eclipses are dealt with in the third chapter comprising twenty six stanzas.

The whole of the fourth chapter is devoted to enjoin the relevant corrections and modifications to be scrupulously effected in order to equalize the computed results namely, the constants, the time and positions of the nine planets etc., with the observational truths.

A very important fact which is revealed to the scholars and researchers on the subject is that *Karanāmrtam* is an independent and original composition brought out by Citrabhanu and presented to the then astronomers who were naturally reluctant to quit the *Parahita* System especially for want of a copious manual of computation in the newly introduced Drk System. It is to be particularly noted that the *Drigganita*, the system revised just before a hundred years, though in four Paricchedas and a summary in the second part, does not give a perfect modus operandi for practical purposes. So that, for a proper appreciation and assessment of the merits of this work or to say with any certainty whether Citrabhanu's *Karanāmrtam* is a complement, supplement or amendments and

improvements (or all these and something more combined together) to the *Drigganita*.[111]

Citrabhanu is a reputed astronomer, gifted mathematician and above all a keen geometrician. His commentary on the first three cantos of the *Kirātārjuniya* makes him one among the great scholars of the land, in the Sanskrit literature also.[112]

Sankara Variyar, the author of the *Kriyakramakari* commentary on the *Lilavati*, was a student of Citrabhanu, for he says that he learnt the methods of proof, etc. from him.[113]

Narayana I (A.D. 1500-75)

Narayana, disciple of another Narayana and Citrabhanu, an ardent admirer of Nilakantha Somayaji and highly devoted to Subrahmanya, an esteemed associate of Nilakantha, was an original thinker and highly informed commentator. He wrote in A.D. 1529, an instructive commentary called *Laghuvivrti* on *Pañcabodha* IV. His *Uparagakriya Krama* in five chapters is a detailed exposition of eclipse computation. He also wrote two commentaries on the *Lilavati*, one short and the other nearly five times as long, both called *Kriyakramakari* and *Karmadipika* (called also

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111 V. Narayana Namboodiri (ed.), *op.cit.*, pp. III-X.
112 K. Kunjunni Raja, *The contribution of Kerala to Sanskrit Literature*, Madras University, 1958, p. 103.
113 K. Kunjunni Raja, Astronomy and Mathematics in Kerala, *op.cit.*, p. 154.

Karmapradipa and *Karmapradipika* according to the exigencies of the meter of the verses containing these names).

Sankara Variyar (A.D. 1500-60): Sankara II

The author of *Laghuvivrti* (A.D. 1556), which is an erudite commentary on the *Tantra Sangraha*, was a disciple of Nilakantha Somayaji and Citrabhanu and protégé of (Netra) Narayana (Azhvāñceri Tamprākkal), both of whom are mentioned in the beginning of that commentary, is identified with Sankara Variyar of Trikkutaveli family. This commentary was composed last by Trikkutaveli Sankara Variyar. It is stated to have been said by Parannottu that it was composed with great care for the sake of Azhvāñceri. The person referred to here as Parannottu is very likely to be Parannottu Jyesthadeva, a younger contemporary of Nilakantha, and, therefore, the statement is quite likely to be authentic.

It can also be shown that the anonymous work entitled *Karanasāra*,[114] in four chapters, whose authorship has been left open and a Malayalam commentary on it which is, at present, attributed to Sankaran Namboothiri of Mahisamangalam are really the works of Sankara Variyar.[115]

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[114] Sankara, Karanasara (vakyanam), Palmleaf, No. C. 8-B, C.173-J, T. 1042, Kerala University Oriental Manuscript Library, MSS.

[115] K. V. Sarma, Contributions to the Study of the Kerala School of Hindu Astronomy, *op.cit.*, pp. 58-59.

Sankara of Mahisamangalam (A.D. 1494-1570): Sankara III

In the matter of the popularisation of studies on Jyothisha among the masses in Kerala, Sankaran Namboothiri of Mazhamangalam (Skt. Mahisamangalam) family had an important part to play. Sankara hailed from the Perumanam village near Trichur but spent most of his active life at Chengannoor with his teacher Parameswaran Potti of Vazhamaveli house.[116] He studied astronomy and astrology from him.[117]

Sankara wrote a large number of works both on astronomy and on astrology, mostly in simple Malayalam poetry and easy prose. Those works include *Ganitasara*,[118] *Candraganitakrama* and *Ayanacalanādi* Ganita in astronomy, *Rupānayanapaddhati* on grammar, *Jatakakrama*[119] in horoscopy and *Prasnamāla*[120] with *Bhāsya* in astrological query. A work which he composed in two versions is the *Kaladipaka*, called in general parlance *Ceriya Kaladipakam* (short *Kaladipaka*)[121] and *Valiya Kaladipakam* (long *Kaladipaka*). He authored a *Jatakasara* in Sanskrit and another with the same title in Malayalam. He had commented on *Pañcabodha* II and *Pañcabodha* IV. His commentaries on

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116 *Ibid.*, pp. 62-63.
117 K. Kunjunni raja, Astronomy and Mathematics in Kerala, *op.cit.*, p. 156.
118 Ganitasara, Palmleaf, No. 3630-F, 6007-B, 6445, 12551-A, Kerala University Oriental Manuscript Library,MSS.
119 Jatakakrama (vidhi), Palmleaf, No. 17539-K, 21125-C, Kerala University Oriental Manuscript Library, MSS.
120 Prasnamala, Palmleaf, 17125-A, T. 213, Kerala University Oriental Manuscript Library, MSS.
121 Sankara, Ceriyakaladipakam, Palmleaf, No. 151-C, 935-D, 1161-D, 1187-B, 3630-A, Kerala University Oriental Manuscript Library, MSS.

Laghubhaskariya, *Muhurtapadavi*,[122] *Pañcabodha* IV and his *Kaladipaka* II, all called *Balasankaram*, have greatly helped the popularization of these works among the people. Sankara is also reputed to have composed a 'Register of Muhurtas' for 1000 years.[123]

Jyesthadeva (A.D. 1500-1600)

Jyesthadeva was the pupil of Damodara of Vatasseri. He was a Namboothiri Brahmin of Parannottu family in Alattur village in South Malabar. He was much younger to Nilakantha and wrote the *Yuktibhasa* or *Ganitanyaya Sangraha*, a unique work giving the rationale and proof or derivation of all theorems and formulae then in use among astronomers.[124] It forms an elaborate and systematic exposition of the rationale of mathematics in its part 1 and of astronomy in its part II. The Sanskrit version of this work, known as *Ganitayuktibhasa*, is also, in all probability, his work. He was the teacher of Acyuta Pisharati who mentions him in reverential terms at the close of his *Uparagakriyakrama* (A.D. 1592). M. Whish, on the '*Hindu Quadrature of the Circle*' records a tradition that the author of the *Yuktibhasa* was the author also of a *Drikkarana*. The *Drikkarana* in question, which is now available in a single manuscript, is a comprehensive metrical treatise in Malayalam on astronomy. It does not

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[122] Balasankara, Muhurtapadavi (vakyanam), Palmleaf, No. 5880, 6446, 10837-A, 10987-A, 17279, Kerala University Oriental Manuscript Library, MSS.

[123] K. V. Sarma, Contributions to the Study of the Kerala School of Hindu Astronomy, *op.cit.*, pp. 62-64.

[124] K. Kunjunni Raja, Astronomy and Mathematics in Kerala, *op.cit.*, pp. 156-157.

give anywhere the name of its author, but gives in its last verse, its date of composition in the words *kolambe barhisūnau* (M.E. 783 = A.D. 1608). In view of this date and the mention of the tradition recorded by Whish, it is quite possible that this is a work of Jyesthadeva.[125]

Acyuta Pisharati (A.D. 1550-1621) Acyuta II

Acyuta Pisharati of Trikkantiyur (Skt. Kundapura) in South Malabar was the disciple of Jyesthadeva and became well known as the preceptor of Melpputtur Narayanabhatta. He is perhaps the greatest non-Brahmin astronomer-mathematician of Kerala. He was a member of the pisharati community, often referred to as vaisnava in Kerala, whose function is to look after the external affairs of the temple. He was a scholar not only in astronomy, but also in Sanskrit, Grammar, Medicine and Literature. Several stories about him are popular in Kerala, many of which connect him with Narayanabhatta. Acyuta Pisharati was patronised by King Ravi Varma of Vettattunad (Sanskritised as Prakasa country) whom he mentions in some of his works. Besides Narayanabhatta, he had another line of disciples in astronomy and astrology, whose contributions have been mainly in Malayalam.[126]

It was he, who enunciated, for the first time, in Indian astronomy, the correction called 'Reduction to the ecliptic', in his work *Sphutanirnaya*

[125] K. V. Sarma, Contributions to the Study of the Kerala School of Hindu Astronomy, *op.cit.*, p. 60.
[126] K. Kunjunni Raja, Astronomy and Mathematics in Kerala, *op.cit.*, pp. 158-160.

(before A.D. 1593)[127] and set out its rationale elaborately in his work *Rasigolasphutaniti.* The *Sphutanirnaya* is in six chapters; there is a veiled reference to his patron Ravi Varma in the introductory verse, as pointed out by the commentator. The *Rasigolasphutaniti* points out that all measurements of longitude and latitude are to be made along the ecliptic and the perpendicular to the ecliptic respectively. In this short work, there is reference to the *Sphutanirnaya* and the *Kriyakrama* as Acyuta's own compositions. The correction in *Sphuytanirnaya* was first introduced in western astronomy by Tycho Brahe[128] at about the same time. The *Pravesaka* is a short primer of Sanskrit grammar. The *Karanottama* is a manual of mathematics in five chapters containing 109 verses. There is a commentary probably by the author himself. The *Uparagakriyakrama*, also known as *Kriyakrama*, deals in 20 verses with the calculations of the solar and lunar eclipses. On astrology Acyuta wrote the *Horasaroccaya* which is an adaptation of Sripati's *Jatakapaddhati.*[129] He also commented in Malayalam on Madhava's *Venvaroha* at the instance of the Azhvāñceri Tamprākkal of his time. Besides the *Chayastaka* and the *Uparagavimsati* is also ascribed to Acyuta.[130]

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[127] K. V. Sarma, Contributions to the Study of the Kerala School of Hindu Astronomy, *op.cit.*, p. 64.
[128] One of the many persons who in the sixteenth century ardently devoted themselves to the new study of nature was the Danish nobleman Tyge (Latinized into Tycho) Brahe (1546-1601).
[129] Jatakapaddhati, Palmleaf, No. 421-B, C.543-B, 2123-B, Kerala University Oriental Manuscript Library, MSS.
[130] K. Kujunni Raja, Astronomy and Mathematics in Kerala, *op.cit.,* pp. 160-162.

Itakramanceri Namboothiri (A.D. 1625-1700)

He is the author of *Bhadradipaganita* (A.D. 1665) but prefers to remain anonymous and refers to himself only by the name of his family, viz., Itakramanceri (or Etakramanceri). He mentions his native place as Perumanur in Malabar and his teacher as Damodaran Namboothiri of the Mangalasseri family. In eleven chapters, couched in easy Sanskrit - Malayalam verses, He provides the laymen with the elements of astronomical computation. A shorter work entitled *Bhugolanayam*, composed in the same style and devoted to a description of the earth as suspended in the atmosphere. Its main landmarks, the construction of the armillary sphere, etc. have much in common with chapter V of the *Bhadradipa* and is likely to be another composition.

Purusottama II (A.D. 1650-1725)

A unique manuscript of the *Uparagapariccheda* of a Pancabodhasataka (Pancabodha v) is known to be written by Purusottama. In forty seven verses, this section of the work sets out the computation of solar and lunar eclipses, using its own revised multipliers, divisors and other constants. For the calculation of the precession of the equinox, it mentions the epoch-*praudhasrigunasevya* (17, 53,242). This date works out to A.D. 1699 and gives a clue to the date of the author.[131]

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[131] K. V. Sarma, Contributions to the Study of the Kerala School of Hindu Astronomy, *op.cit.*, pp. 66-68.

Putumana Somayaji (A.D. 1660-1740)

The *Karanapaddhati*,[132] in ten chapters, is a comprehensive treatise on astronomy by an anonymous Somayaji of the Putumana or Putuvana (Skt. Nutanagrha or Nutanavipina) family of Sivapuram (Trichur). It is a popular manual of advanced mathematics explaining from first principles the methods of deriving the various formulae and tables which are used for calculations in astronomy. The work became quite popular not only in Kerala, but even in Andhra and Tamilnadu; there are two old commentaries of the work in Malayalam, besides a modern exposition by P.K. Koru. Two Tamil commentaries and a Sanskrit commentary are also known.[133] The *Karanapaddhati* which follows the *Parahita* System advocates the *Drigganita* System only in the calculation of eclipses. But the mathematical problems discussed are of universal application. In ten chapters it explains many of the mathematical problems like the Kuttakara method, the derivation of the value of II, the sines of angles, and the positions of the planets. *Karanapaddhati* uses theorems given in earlier works like the *Tantra Samgraha*.[134] The availability of manuscripts of the work in Tamil and Telungu scripts indicate its popularity in those regions as well. Its date of composition falls in A.D. 1732. While *Karanapaddhati* is the best known

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[132] Karanapaddhati (vakyanam), Palmleaf, No. 5586-A, 11076-A, 12577-A, Kerala University Oriental Manuscript Library, MSS.

[133] Kunjunni Raja, Astronomy and Mathematics in Kerala, *op.cit.*, p. 162.

[134] *Ibid.*, p. 164.

work of the author in Jyothisha, it has shown that he has written certain other works also in that discipline. In *Nyāyaratna*, he deals, in eight chapters, with certain aspects of Sphuta, Viksepa, Chaya, Viparitacchaya, Grahanasrngonnati, Maudhya and Vyatipata. The *Nyayaratna* occurs in two versions, which differ slightly by the presence or absence of certain verses and in the arrangement there of. The *Venvarohastaka* of Putumana Somayaji is a manual for the accurate determination of the moon at short intervals. His *Pañcabodhya* III is a practical manual for the computation of Vyatipata, Grahana, Chaya, Srngonnati and Maudhya. *Grahanaganita* IV commences with the characteristic introductory verse of Putumana Somayaji, and so is likely to be his work. So also *Grahanastaka II*, which, though a self-contained work, forms a part of the said *Grahanaganita*.[135] K. Rama Varma Raja makes mention of a tradition which attributes to Putumana Somayaji a work called *Manasaganitam*. This is likely to be the Malayalam commentary on (*Laghu*) *Manasa* which has now been identified and whose introductory verse contains words reminiscent of Putumana Somayaji's expressions. In horoscopy, he wrote the highly popular *Jatakadesa (marga)* which is known in two recessions, both of which might have been written by him.[136]

[135] Grahanaganita, Palmleaf, No. 1005-F, 72367-B, Kerala University Oriental Manuscript Library, MSS.

[136] K. V. Sarma, Contributions to the Study of the Kerala School of Hindu Astronomy, *op.cit.*, pp. 68-69.

Bharadvaja Dvija (A.D. 1750-1800)

An astronomer who called himself merely as Bharadvaja composed two important works, viz., (1) *Ganita yuktayah* which sets out the rationale of several mathematical and astronomical procedures and (2) *Karanadarpana*, an advanced manual for astronomical computation. The former work cites frequently a 'Bhasyakara' who is, obviously, Nilakantha Somayaji, Jyesthadeva, the author of *Yuktibhasa*, and *Nyayaratna*, most probably the work of that name by Puthumana Somayaji. The Karanadarpana has been commented in Malayalam.

Narayana of Perumanam: Narayana V

Narayanan Namboothiri of Perumanam village, near Trichur, is the author of an astronomical treatise entitled *Tantrasara*.[137] There is also a Malayalam commentary available on the work which is an anonymous one.

Krishnadasa (Koccu krishnan Ashan) (A.D. 1756-1812)

Koccu-krishnan Ashan was born in the family of Netumpayil in the Tiruvalla taluk of Kerala, as the son of an erudite astrologer named Raman Ashan. He studied Jyothisha under his father as also under Sulapani Variyar of Kozhikode. He came of a long line of astronomers and astrologers and had several disciples who continued that tradition. He was a great devotee of God Krishna and was a poet with several works to his credit. His works

[137] Tantrasara, Palmleaf, No. 22226-D, 22545, Kerala University Oriental Manuscript Library, MSS.

on Jyothisha, all intended for the novice, include *Pañcabodha* VII, in Malayalam verse, *Bhasajatakapaddhati*, being a free rendering cum commentary of the popular Jatakapaddhati of Parameswaran of Vatasseri, incorporating several matters not dealt within the original. *Kanakkusastram* presenting mathematical procedures in Malayalam verse and a *Bhāsa Golayukti* which he mentions in his *Bhāsajataka paddhati* as a work which he intended to write but which yet remains to be traced.

A hitherto unknown work of Krishnadasa is a commentary in Malayalam prose on the *Āryabhattiya*. The commentary is elucidative and quotes several authorities including Bhāskara I, Laghubhaskariya, Sangamagrama Madhava, Parameswaran of Vatasseri, Karanapaddhati and a Prakasika which remains to be identified. A Malayalam quotation from Parameswaran poses a problem, for all known works of Parameswaran in Sanskrit. Possibly, Parameswaran might have written in Malayalam also or the passage in question is only a view of Parameswaran expressed in Malayalam.[138]

Astronomical Literature of Kerala during the modern period

It should be noted that the periodical revision of astronomical computation continues in Kerala till date.

[138] K. V. Sarma, Contributions to the Study of the Kerala School of Hindu Astronomy, *op.cit.*, pp. 73-75.

The point might be illustrated by three works on the subject composed during the last few decades, all in Sanskrit, employing revised methodologies and incorporating novel corrections, some of them based on modern astronomy. The *Ganitanirnaya* of Puliyoor Prushottaman Namboothiri is an extensive treatise in about 700 verses, divided into ten chapters.

The work takes the end of the Kali year 5,000 equivalent to April 13, 1899, as the epoch and presents the several computations in the traditional fashion. Numerous corrections based on modern astronomy have been incorporated in the Sanskrit verses, including thirteen corrections for the Moon. The *Ganitaprakasika* of Rama Potuval is another modern astronomical manual which, too, takes Kali 5000 (A.D. 1899) as the epoch. In seven chapters containing 265 verses, the author aims at composing a treatise closely following the Kerala method of presentation but adopting new corrections so as to arrive at latest results.

The *Suddha Drigganta* of Kunhikkana Potuval is still another manual of the said type. In eight chapters, containing 123 verses, this work, too, aims at accurate astronomical computation, the entire matter being presented on orthodox lines. It is interesting to note that the Indian

Independence Day, viz., 15th August, 1947, has been adopted as the epoch of this work.[139]

Some of the other astronomical works of Kerala during the modern period are:

Ghatigopa (A.D. 1800-60)

Ghatigopa, which is, presumably, not his real name but only the Sanskritisation of his personal or popular name, calls himself a disciple of Parameswaran and a devotee of God Padmanabha, the presiding deity of Trivandrum. His contribution to astronomy is in the form of two commentaries on the *Āryabhhattiya*, one in Sanskrit and the other in Malayalam on the *Āryabhhattiya*. The commentary in Malayalam occurs in two distinct versions, the longer one being nearly one and a half times in extent as the shorter. In the shorter version, under Kalakriya 4, Ghatigopa gives the rationale for the 248 Candravākyas.

Goda Varma, Vidvan Ilaya Tampuran (A.D. 1800-51)

Among the renowned scholars and patrons of literature produced by the scholarly royal house of Kotungallur, near Cochin, Goda Varma, better known as Vidvan Ilaya Tampuran, occupies a permanent place in the front rank. He was a versatile scholar and has written profusely, both in Sanskrit

139 *Ibid.*, pp. 15-18.

and in Malayalam. In Sanskrit on the *Ganitadhyaya* (*Bhaskariyaganita*) and the *Goladhyaya* of the *Siddhanta Siromani* of Bhāskara II.[140]

Sankara Varma of Katattanad (A.D. 1800-38)

Sankara Varman of Katattanad, author of the *Sadratnamala*,[141] was also known as Appu Tampuran and flourished in the first half of the nineteenth century. He was the brother of King Udaya Varman and the heir apparent. Sankara Varman of the royal family of Katattanad in North Kerala was born in A.D. 1800. The *Sadratnamala* is a comprehensive work in six chapters and contains all the results of Kerala mathematical studies, without the deductions. The date of composition of the work corresponded to A.D. 1823. He was patronized by Swathi Thirunal Maharaja of Travancore. Sankara Varman also wrote a Malayalam commentary on the work, extending till the middle of the sixth chapter. He died at an early age in A.D. 1838.[142]

Rama Varma Koyil Tampuran (A.D. 1853-1910)

Rama Varma of the royal house of Gramam was a scion of the principality of Parappanat. He was a versatile scholar and author of several literary works. He studied Jyothisha under Prince Ampuraja at the

140 *Ibid.*, pp. 77-78.
141 Sankara Varman, Sadratnamala, Palmleaf, No. 8322-B, C-2136, Kerala University Oriental Manuscript Library, MSS.
142 K. Kunjunni Raja, Astronomy and Mathematics in Kerala, *op.cit.*, pp. 165-166.

Chirakkal Palace in North Malabar and composed, in that discipline, the Jyothishapradipa, an instructive introduction to astronomy.

The later phase

Among later scholars who continued the tradition of Jyothisha and who, by their expositions and interpretations, helped to sustain and promote astronomical and astrological studies in Kerala, a mention should be made of four important names: (1) Rama Variyar of Kaikkulangala (1833-97), author of *Samudrikasastra* and *Gaulisastra* and commentator of *Hora* and *Prasnamarga*; (2) Rajaraja Varma Koyil Tampuran (1853-1918) who wrote two studies entitled, *Karanapariskarana* and *Pañcangasuddhi paddhati.* (3) Vasunni Mussatu of Vellanasseri (1855-1914), author of an erudite commentary in Malayalam on Pañcabodha; and (4) Punnasseri Nampi Nilakantha Sarma (1858-1935) who compiled a very instructive manual on astronomy under the title *Jyotissastra Subodhini* with an extensive elucidation and wrote a *Pañcabodhakriya Bhāsa*, besides commenting, elaborately, on the *Camatkaracinta mani* and the *Prasnamarga.*[143]

The members of the Kerala School were predominantly (Namboothiri) Brahmins with a few who came from other castes, such as the Variyars and the Pisharatis, traditionally associated with specific duties in the temple. Within a mainly two-tier caste system, consisting of

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[143] K. V. Sarma, Contributions to the Study of the Kerala School of Hindu Astronomy, *op.cit.*, pp. 80-81.

Brahmins and Nairs, two institutions operated to strengthen and sustain the economic and social dominance of the Namboothiris to a degree not known elsewhere in India: the Janmi system of land holding and the Namboothiri control of vast-tracts of land owned by temples.

Madhava and all those who knew and followed him lived and worked in large compounds called *illoms* in villages with predominantly Namboothiri settlements. Set well away from roads to prevent contact with others, often surrounded by a high wall, each *illom* had its own well for water, a tank for bathing and a number of out buildings. Many of these *illoms* belonged to households that owned large landed properties and were very affluent. With their estates farmed by workers or tenants from lower castes and often under the management of Nairs, the Namboothiris, and particularly the younger sons, enjoyed considerable leisure and were expected to pass their time in study and ritual observations.

These *illoms* provided a base for the education of the young in Sanskrit works, including mathematical and astronomical classics, notably the *Āryabhattiya* of Āryabhatta (b. A.D. 476) and its commentaries. Not only was traditional knowledge transmitted in these *illoms* by rote, but they also provided a centre for research and scholarship. Sometimes, the scholars wrote commentaries on the classics and in those commentaries they appended their own discoveries as additions and supplements. The short distances between the *illoms*, the role of the temple and political stability

combined to provide for long and stable development, usually based on generations of teacher-student relationships. A study of their interaction with certain temple personnel (especially, the *ambalavasis* or castes of temple servants) such as Sankara Variyar and Achuta Pisharati might shed light both on how non-Brahmin Hindus were recruited into their circle as well the process by which a wider dissemination of the results of their work in mathematics and astronomy took place into the neighboring areas especially in the Tamil region.

Even a cursory examination reveals the heterogeneous nature of the social background of the members of the Kerala School. While most of them were Namboothiri Brahmins, there were some notable ones who were not. This included Madhava, the founder of the school, who was an Empran Brahmin or a member of a Brahmin group from the Karnataka districts beyond the northern border of Kerala. And he was pursuing activities such as studying mathematics and astronomy which perse did not constitute 'high status' activities. On the other hand, the most notable member after Madhava, Neelakantha belonged to the highest rank among the Namboothiris. He was a Somayaji, one of the select sub castes among the Namboothiri's, who could carry out the Soma sacrifices. But then there were other members of the Kerala School who were not even Brahmins, such as Sankara Variyar, where the name Variyar indicated that he belonged to the Ambalavasis, a caste of temple servants. And similarly with

Achuta Pisharati. It would indicate that the composition of the Kerala School was more mixed than one would have expected. They constituted an interesting group brought together by their interest in mathematics and astronomy which did not have great social value or status, a group that to some extent cut across caste lines and a group who probably had considerable interactions with the temple personnel.[144]

There was a lull in the activities of Kerala mathematicians after the time of Sankaravarman. No new ground was explored, since the needs astrological astronomy was already satisfied. Western domination of the country had a degrading effect on all indigenous studies and there was no serious attempt to correlate western mathematics with Kerala methods. There were great astrologers like Goda Varma Yuvaraja of Cranganore and Maccat Iiayat, but no work of importance on astronomy or mathematics has come from them.[145]

During eighteenth, nineteenth and twentieth centuries, the British tried to utilise astronomical science for their commercial interest and political ambition. The promotion of the knowledge of astronomy, geography and navigation in India enabled them to know the latitude and longitude of India and thereby to expand their territories.

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144 G. G. Joseph, *Infinite series in Kerala: Background and Motivation*, International seminar on Aryabhatteeyam, pp. 133-134.

145 K. Kunjunni Raja, Astronomy and Mathematics in Kerala, *op.cit.*, pp. 166-167.

CHAPTER - 3

THE TRIVANDRUM OBSERVATORY

Travancore deserves special attention for its initiatives in the field of science and scientific investigations. The establishment of an observatory at Trivandrum even in the beginning of the nineteenth century forms part of that enthusiasm.[1] The rulers of Travancore encouraged the development of astronomical science. There was a court astronomer as well as an astrologer employed to make arrangements in the city for announcing the times of the day, for predicting the eclipses, for fixing *muhurtas* (auspicious moments for rituals and social ceremonies), casting of horoscopes, horary astrology, etc. This interest led to the establishment of an institution for the growth of astronomical science.

The Trivandrum Observatory owed its origin in 1836 to the enlightened views of His Highness Rama Varma (Swathi Thirunal, A.D. 1829-47), then reigning Raja of Travancore, and to the encouragement given to him by the late General Stuart Fraser, then representative of the British Government at Trivandrum.[2] The reign of Swathi Thirunal (A.D. 1829-47) was one of the most eventful periods in the history of Travancore.

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1 S.Raimon (ed.), *Archives Treasury*, Kerala State Archives, 1994, p. 56.

2 John Allan Brown (ed.), *Observations of magnetic declination made at the Trivandrum and Agustia Observatories in the observatories of His Highness the Maharaja of Travancore in the years 1852 to 1869*, London, 1814, p. 5.

During that period noteworthy improvements were made in many departments and new institutions of useful character were established. His Highness was a patron of both arts and letters and His Highness's fame extended throughout the length and breadth of India for his love and encouragement of science and arts. His Highness had marvelous poetical gifts, he was both a composer and singer of both Hindustani and Carnatic music, and had mastery over several languages.[3] His Highness was himself a keen student of astronomy[4] and his interest led to the establishment of an Observatory at Trivandrum.

Development of Astronomical Science under the British:

The study of astronomy and allied sciences regained importance in India with the establishment and gradual expansion of the suzerainty of the East India Company. Thomas Deane Pearse (1741-89) of the Bengal artillery undertook a series of observations of latitudes and longitudes from 1774 to 1779 and again from 1781 to 1784 during his marches to and from Madras in the Mysore war.[5]

Nothing however was done until 1786, when Sir Archibald Campbell, Governor of Fort St.George (A.D. 1786-89) ordered an astronomical survey. In September 1787 he informed the council that he

3 Cover files, 1857, C. No. 16086, B. No. 28, p. 2.
4 *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, Trivandrum, 1937, p. 37.
5 Priyaranjan Ray and S. N. Sen, *op.cit.*, p. 261.

had, in the previous November, engaged Michael Topping, 'a person of very considerable mathematical and geographical knowledge, 'to fix the latitude and longitude of the principal coast stations north of Masulipatnam. The observations made by Topping during his overland journey to Calcutta were submitted, and the council resolved that he should continue his work south ward to Cape Comorin, and, after determining the exact coast-line, ascertain the position of the principal places in the Carnatic[6] Topping began the southern survey in 1788, and secured the services of John Goldingham to make corresponding observations at Madras.[7]

The motive behind the British to develop astronomical science was their commercial interest and political ambition and also 'for promoting the knowledge of Astronomy, Geography and Navigation in India[8] and to know the latitude and longitude of India to expand their territories.[9] The main reason for showing an accurate interest in astronomy is that, the British authorities found it necessary to prepare accurate maps of the territory under their control and of the sub continent in general and to expand their territories. This required accurate determination of longitudes and latitudes of important places. The longitude of the Madras Observatory

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6 Henry Davison Love, *Vestiges of old Madras*, London, 1913, p. 346.
7 *Ibid.*, p. 347.
8 *Silver Jubilee Souvenir of the Regional Meteorological Centre*, 1945-1970, India Meteorological Department, p. 3.
9 C. D. Maclean, *Manual of the Administration of the Madras Presidency*, Vol.1, New Delhi, 1987, p. 519.

had an important role as a fundamental meridian from which observations for longitude in the Indian survey were reckoned. The accuracy with which a map of India fits into a map of the world depends solely on the accuracy of the longitude determination of the transit instrument pier at the Madras Observatory.[10] The Madras Observatory participated in observation and discovery of new planets, minor planets and comets, especially when such are invisible to European astronomers.[11]

Indian Observatories

Astronomical observatories existed in a crude form from ancient times. An observatory is an institution or a building constructed and used for the purpose of making astronomical, meteorological or other kindred, scientific observations.[12] The first Astronomical observatory in India with a telescope was established in Madras during 1792, by the British East India Company.

Michael Topping persuaded the Court of Directors for the establishment of an (astronomical) observatory at Madras which would be of great advantage to science. In 1871, Topping was deputed to build the observatory. Sir Charles Oakley being then Governor of Fort St. George, the observatory came into existence at Madras in 1792. It originated from a

[10] Priyaranjan Ray and S. N. Sen, *op.cit.*, pp. 261-262.
[11] C. D. Maclean, *op. cit.*, p. 520.
[12] R. Radha, *Climatology*, part-I, Tamil Nadu Book Society, 1971, p. 9.

small private observatory started in 1787, by William Petrie, a scientific member of the Government of Fort St. George. He had built an observatory at his private expense, probably the first modern astronomical observatory in the east.[13] A separate 20 ft X 40 ft single room was constructed in 1792 as the observatory[14] at Nungambakkam, Madras. Topping functioned as the first astronomer of the observatory.[15] During the time of Michie Smith, the Astronomer to the Government of Madras in 1881, Kodaikkanal in upper Palani Hills was chosen for the location of the proposed solar observatory.[16]

The scheme for the reorganization of the Indian observatories came into force from 1 April 1899. From that date, the Madras Observatory was transferred from the Government of Madras to the Government of India. The former astronomer became the Director of Kodaikkanal and Madras Observatories. From that date, the astronomical work in the Madras Observatory came to an end, except for transit observations for time determination.[17]

The second observatory in India founded by the English East India Company was at Colaba, Bombay. A site was selected for an astronomical

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13 C. D. Maclean, *op. cit*., p. 519.
14 India's National Magazine, *Frontline*, Volume 16-Issue 13, June 19-July 02, 1999.
15 Public Despatches to England, dated 16 January 1792, Tamil Nadu Archives.
16 *Silver Jubilee Souvenir prepared by Director General V. V. Sohani on the occasion of silver jubilee Year*, Kodaikkanal Observatory, 1901-1951, p. 2.
17 *Report on the Administration of the Madras Presidency* (1900-1901), p. 162, Tamil Nadu Archives.

observatory in 1823 and the main building was constructed under the direction of Curnim, the astronomer in Bombay.[18]

The ruler of Oudh established an observatory at Lucknow around 1832. Wilcox assumed charge and made some observations at this observatory, but it was closed in 1849 following his death.[19] There were also observatories started by individuals due to their personal interest such as Juggarow Observatory at Vizagapatnam. The observatory was established in 1841, by Juggarow Garu, the Zamindar of Vizagapatnam district which was used to fire time gun for indicating time to the public and was latter discontinued.[20]

Towards the last decade of the nineteenth century an observatory was started at Poona called the Maharaja Takhta Singji Observatory, it commenced its activity under the direction of professor Naegamvala. A part of the nucleus of the funds that were needed for the starting of the observatory was provided by the Maharaja of Bhavnagar. This observatory had the largest telescope in the country then, a twenty inch reflector. It also had several smaller instruments which were principally used for eclipse observations. The most important work done here has been the observations of the solar corona of 1898. The Naegamvala expedition to Jeur and the

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18 *Hundred years of weather service* (1875-1975), India Meteorological Department, p. 13.
19 Priyaranjan Ray and S. N. Sen, *op.cit.*, p. 265.
20 A. V. Juggarow Garu, *G. V. Juggarow Observatory*, Madras, 1904, p. 18.

successful observation of the corona and its spectrum form the first complete Indian effort of its kind on record.[21] It was closed in 1912 and some of the instruments were sent to the Kodaikkanal Observatory.[22]

The Trivandrum Observatory survived to the present day. Madras Observatory lasted till 1900 and others did not survive more than a decade.[23] While the work of Kodaikkanal Observatory was restricted to solar physics up to the end of World War II. Since 1946, the activities of the observatory were expanded in several directions. Apart from the study of the sun, work in stellar physics, radio astronomy, cosmic radiation, ionospheric physics etc. is also being done.[24] Consequent to the recommendation of the Committee for Organization of Scientific Research (COSR) headed by S. Bhagavantam, the Government of India separated astrophysics from India Meteorological Department and reconstituted the Kodaikkanal Observatory as an autonomous institution named "Indian Institute of Astrophysics" from 1 April, 1971.[25] These were the various observatories started during the British period.

21 Priyarajan Ray and S. N. Sen, *op.cit.*, p. 262.
22 *Hundred years of weather service* (1875-1975), p. 169.
23 T. E. Girish, "Hindu astronomy and Kerala culture", *op.cit.,* p.149.
24 *Hundred years of weather service* (1875-1975), p. 171.
25 *Ibid.*, p. 173.

Origin and development of astronomical science in Kerala during the British period

Maharaja Swathi Thirunal had a good knowledge of the Hindu science of astronomy. Due to his interest to develop it, He had often discussed the subject with the then commercial agent of Alleppey, John Caldecott, who being well versed in that science, used to make astronomical observations with several portable instruments of his own. He had been engaged in mercantile speculations. Caldecott's descriptions of his observations of the various movements of the heavenly bodies, closely corresponding with the calculations and observations of the Hindu astronomers, the Maharaja was most anxious for a thorough investigation of this science.[26]

The appointment of Caldecott: The First Astronomer

At about this time, the Maharaja being on a tour to the northern districts, visited Alleppey, and had thus an opportunity of examining several interesting astronomical instruments, belonging to Caldecott, who suggested the construction of a small observatory at Alleppey, but the Maharaja wished to have a good building erected at Trivandrum. His Highness therefore desired Caldecott to make an official proposal, through

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[26] P. Shungoonny Menon, *History of Travancore form the earliest times*, New Delhi, 1978, p. 415.

the Resident, Colonel Stuart Fraser, for the construction of an observatory at Trivandrum. Col. Fraser, an amateur of science took up the proposition warmly and brought it to the notice of His Highness Rama Varma.[27] The measure was duly proposed, and it having been readily sanctioned by the Maharaja, Caldecott was appointed as His Highness astronomer, made him its director.[28] Morphew was appointed as commercial agent in charge of the Commercial Department in the place vacated by Caldecott. In the letter of the British Resident of Travancore to the Diwan dated 8 November 1836, he stated that Caldecott's appointment to the Trivandrum Observatory should take place on the same date as the appointment of Morphew as commercial agent.[29]

The reason for an observatory at Trivandrum was that the institution was intended to give an impetus to science by taking advantage of the fact that the magnetic equator, the line on which the magnetic needle dips neither to north nor to south passes through the state[30] and that the Maharaja desired that his country should partake with European nations in scientific investigation.[31]

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27 Cover Files, 1857, p. 2.
28 John Allan Brown, *op.cit.*, p. 5.
29 Cover Files, 1836, File No. 14935, B. No. 10.
30 *Travancore Administration Report*, (1933-1934), p. 247.
31 S. N. Sen and K. S. Shukla (ed.), *History of Astronomy in India*, New Delhi, 1985, p.389.

Plan of the observatory

The Maharaja, desirous of introducing knowledge of European engineering art into Travancore, in consultation with Resident Colonel Fraser, sanctioned the organization of an experimental engineering department, and Lieutenant Horsley was offered the post of a visiting engineer and superintendent of Irrigation and other important works at Nanjenaud and Trivandrum.[32]

In the letter of Caldecott to the Diwan dated 31 August 1836, the astronomer requested the Diwan to show His Highness the plan for the intended observatory prepared by Horsley and to inform him of any suggestion or alteration that His Highness may make.[33] The Maharaja gave his sanction to the proposed plan. The site chosen was the highest hill in Trivandrum, nearly 195 feet above the sea level, being the top of a hill commanding a good view on all sides. The top of the hill gave excellent view of the horizon particularly on the western side.[34] The building, planned by and erected under the superintendence of captain Horsley, of the Madras engineers, was commenced in October 1836 and was nearly finished in the middle of the following year.[35] The construction of the observatory confirmed the engineering skill of the Europeans. The practical

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32 P. Shungoonny Menon, *op.cit.*, p. 417.
33 Cover Files, 1836, File No. 16133, B. No. 10.
34 *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p. 38.
35 Cover Files, 1857, p. 3.

reason for the construction of the observatory bang opposite the Kanakakunnu palace was that this spot is topographically the most elevated location in the city.[36]

The plan of the building, which has no architectural merits, was nearly rectangular, 78 feet long in the direction east and west, and 38 feet broad. The height from floor to ceiling is 14 feet, the central part, 52 feet by 14, was terraced, and the outer parts or verandahs were covered by sloping roofs. The transit room and circle room are each 14 feet by 12; the instrument pillars erected on the laterite rock were solidly built of granite. In the centre of the lobby (20 feet by 12) a well-built granite pillar, carried 20 feet above the floor, is covered on the terrace by a dome 10 feet in diameter. This pillar was intended for an altitude and azimuth instrument. The south corners, 13 feet square, were built up of solid laterite to the height of the terrace, and covered with domes, one was intended for a refracting the other for a reflecting equatorial, niches in the sides of the central pillar were made for clocks. The openings for the transit instrument and two circles were carried across the terrace and verandahs, and were composed of so many parts as to require men, on watch, for the purpose of opening or shutting them by hand. The verandah rooms were occupied as computing rooms.[37]

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36 *The Hindu*, 4 November 2005, p. 6.
37 Cover Files, 1857, p. 5.

Position of the observatory

The Trivandrum observatory is situated in Latitude……..8^{0} 30' 32"N (eighty degrees, thirty minutes and thirty two seconds) Longitude from Greenwich…..5^{h} 7^{m} 59^{s} E and the height of the floor above the level of the sea is 195 feet. The observatory occupied the crown of a small hill, celebrated by travelers for the magnificent view which it commanded. The sea, within two miles at the nearest, is seen from the south to the west north west points of the horizon, bordered by a thick and continuous grove of coconut trees. The surrounding areas around the observatory is an alternation of hill and valley, the former crowned inland by forests and castellated masses of granite, the latter covered with rice fields fringed with plantain and palm trees, present in many places during the monsoon the appearance of lakes and winding rivers, and at other times that of fertile meadows, whose rich green covering was bending to the harvest. On the east the many peaked Ghats rise up like a wall, shutting out the warmer world of the Madras presidency. The nearest distance, from the observatory to the mountains would be about twenty two English miles. This was the position of the observatory in 1836.

Building

Though the granite protrudes in huge masses from place to place, yet the observatory hill, like most others within a few miles of the sea, is formed of the rock peculiar to India called laterite, sufficiently soft to be cut into blocks for building purposes with a hatchet, the walls of the observatory are built of sand founded on this rock.[38]

Caldecott was asked to construct additional buildings for magnetic and meteorological observations and to make a continued system of observations relating to terrestrial physics, especially to terrestrial magnetism[39] due to the fact that Travancore offered special advantage in this direction and as the magnetic equator passes across the country. Caldecott, however, started a regular system of meteorological observations from July 1837, and a meteorological observatory was built in 1841.[40] In 1842 another building was erected to the north-west for the reception of an equatorial, constructed by Dolland. The central part was occupied by the instrument, and the small rooms around were used for the library.[41]

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38 Ibid., p. 5.

39 Terrestrial magnetism means the magnetism of the earth which is also known as geomagnetism. It involves any topic pertaining to the magnetic field observed near the earth's surface, within the earth, and extending upwards to the magnetospheric boundary.

40 *Souvenir of the Centenary of His Highness the Maharaja's Observatory,* p. 38.

41 Cover Files, 1857, p. 5.

The Library

The library occupied a place in the equatorial building. It consisted of several excellent works including the transactions of several learned societies. It had been little cared for as some of the most valuable books were perforated by white ants.[42]

Purchase of Astronomical Instruments:

Caldecott started making observations in July 1837, to start with using his own instruments. However, in the following years on the advice of Raja Rama Varma, he went to Europe for the purchase of a permanent instrument outfit[43] and was authorized to furnish the institution with the best instruments from Europe.[44]

Before leaving India Caldecott had made an arrangement with his brother William Caldecott in England for the purchase of the observatory instruments. He requested the Diwan of Travancore to make part payments to his brother for the purchase of the instruments for the Trivandrum Observatory, for which he received bills from England for £ 1,500. He asked the Diwan to transmit the bills to his brother which should be accompanied with a letter of the Diwan informing him that they were sent

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42 Ibid., p. 17.
43 S. N. Sen and K. S. Shukla (ed.), *op.cit.*, p. 389.
44 Cover Files, 1857, p. 3.

to his care by the advice of the astronomer, John Caldecott so as to enable him to make the requisite advances to the makers of the instruments.[45] These letters and instructions were transmitted to England with the approval of the Maharaja.

Caldecott requested the Travancore Government as not to employ the Sarkar agents or any other mercantile house either at Madras or London as he thought that justice could not be done by them as the agents in London would draw on Madras for the advances and the Sarkar would be charged with all the losses in exchange. So the astronomer asked the Diwan to entrust the whole matter to him regarding the requisite degree of attention, both for the communication of the orders for the respective artists and for finishing the instruments in the first degree of excellence.

Accordingly, the Government entrusted the whole work of purchasing the instruments to Caldecott. The three principle instruments and the makers employed were a five feet mural circle by Troughton and Simms and a five feet mural circle by Iones and the third instrument was a five feet transit instrument by Dolland.[46] Troughton and Simms, Iones were the makers of the two mural circles used at the Royal Observatory at Greenwich, London

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[45] Ibid., 1838, C. No. 15966, Lt. No.VI, B. No. 13.
[46] Ibid., Lt. No. VIII.

Caldecott's journey expense to and from England was fixed at £ 250 which was paid by the Government of Travancore. Caldecott left England in December 1838 through the Red Sea and Egypt.[47] In England, he had superintended the completion of the instruments. An equatorial, an altitude and azimuth instruments and clocks were written for.[48] Caldecott, while still in Europe waiting for construction of the astronomical instruments, received the Raja's permission to purchase other instruments to furnish a magnetical and meteorological observatory. Travancore offered special advantages in this department, as the magnetic equator, the line on which the magnetic needle dips neither to north nor to south passes across the country.[49] His Highness allowed Caldecott to obtain a complete set of magnetical and meteorological instruments. This observatory was built in 1841. Several portable instruments belonging to Caldecott were put into use at once and a system of meteorological observations was commenced at the same time (July 1837).[50] The instruments obtained by Caldecott for the magnetical observatory were of the same construction as those supplied to all observatories in the British dependencies, newly devised by the Lloyd, and employed by him in the Dublin observatory.[51]

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47 Cover Files, 1838, Lt. No. II.
48 Ibid., 1857, p. 3.
49 J. A. Brown, *op.cit.*, p. 6.
50 Cover Files, 1857, p. 3.
51 J. A. Brown, *op.cit.*, p. 6.

Caldecott returned back to India in the year 1841, and the instruments brought by him were installed in their places during that year itself.[52] As a result of Caldecott's efforts the observatory was equipped with the mural circles by Simms and Jones respectively, a transit and a seven and half feet equatorial by Dolland, an altitude and azimuth instrument and a few astronomical clocks.[53]

First Astronomical Instruments

Britain co-operated with every new discoveries made by the company's astronomers. They sent new instruments from England in pursuit of astronomical discoveries. A description of the first astronomical instruments of the Trivandrum Observatory is given below.

The Transit clock

The Transit clock by Dent is of the best construction, the pendulum bracket is fixed to the granite pier of the observatory. On the other side of the pillar a clock by Wrench occupies the niche; it is also of the best kind.

The mural circle

The mural circle by Troughton and Simms is placed on the east side of the pillar. This is of the same construction as that by the same artists used

[52] *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p. 38.
[53] S. N. Sen and K. S. Shukla (ed.), *op.cit.*, p. 389.

at the Greenwich Observatory. The mural circle has an aperture of object glass of four inches; diameter of circle-five feet. The mural circle by Jones is placed on the west side of the pillar. In Troughton and Simms circle there are two weights each having a lever that carries a friction wheel, on the friction wheels the circle axle rests. In jones circle there is a single counter poise and lever carrying a chain that passes round and supports the axle.

The Equatorial

In 1842 another building was erected to the North-West for the reception of an equatorial, constructed by Dolland. The focal length of seven feet, aperture of object glass five inches, circles two feet and four inches-diameter. An observation chair with rack work motion for moving the seat up and down on a curved frame was also brought out from England for this instrument. A small equatorial was fixed to a strong wooden post under the dome, focal length of five feet aperture of 4.2 inches.

Two portable altitude and azimuth instruments

These instruments by Troughton and Simms with horizontal circles of fifteen inches and twelve inches and vertical circles of fifteen inches and eight inches respectively also belonged to the observatory.[54] The Transit circle and other astronomical instruments and clocks were installed in

54 Cover files, 1857, p. 7.

1841.[55] In one of the letters dated January 4, 1840 by the Raja of Travancore to the Director of the observatory the Raja expressed his regret after learning about an intimation that Caldecott had received from the resident that the Raja frequently evinced to him much regret at the expenses incurred on account of the observatory establishment and that in consequence, the Raja is inclined to abolish that institution altogether. On this the Raja expressed that neither such mean idea had ever entered into his head, but on the contrary he expressed his sense of high advantage derived from the establishment of the observatory and stated that it is his sincere wish to continue the observatory permanently as he is always resolved to assist and promote the establishment as far as it lies in his power. The Raja requested Caldecott to cast off any suspicion upon this as he is afraid that it is purposely excited to create misunderstanding between them and he firmly asked Caldecott to rely upon his foregoing assurances.[56]

Although there were such assurances from the Raja of Travancore, the Government was compelled to ask an explanation to the Resident of Travancore regarding the excess of expenditure in purchasing astrononomical and other philosophical apparatus for His Highness the Raja's Observatory and was asked to submit the reasons regarding it. The Diwan of Travancore

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[55] V. Nagam Aiya, *The Travancore State Manual*, Vol. 1, New Delhi, 1989, pp. 488-489.

[56] From the archives of Royal Society of London, purchased by Dr. Achuth Sankar S. Nair and also in appendix 1.

handed over the memorandum to Caldecott of the amount advanced at different times on account of the purchase of the astronomical apparatus, which had greatly exceeded the estimate fixed by the Government.[57]

Accordingly Caldecott was obliged to furnish with satisfactory reasons for the excess of expenditure. He submitted the statement of expenditure made on the instruments and books that he had purchased for the observatory which is given below:

	£	pounds	shills'
Astronomical Instruments	3752	15	4
Meteorological Instruments	303	9	6
Magnetical Instruments	613	9	5
Books	345	10	2
	5015	4	5

Caldecott stated that he is aware that the amount shown above exceeded the authorized amount of the Sarkar but provided the information that everything which was purchased would be highly necessary and useful in the future operations of the observatory and that the Sarkar need not fear on the expense of the excess, as it is inconvenient to continue the observations

57 Cover Files, 1841, C. 15851, B. No. 16.

without the necessary instruments. The astronomer added that no where there has an observatory so complete and efficient as this would be, been furnished at so comparatively trifling an outlay as most of the items were accompanied by vouchers which were referred to by the small figures to the left hand side.[58]

Separation of the press from the observatory

In the beginning, as there were no astronomical instruments, mere calculation work was done, and the results were published as Astronomical Ephemeris adapted to the meridian of Trivandrum Observatory. The first Astronomical Ephemeris or Travancore Almanac was issued in 1838. This Ephemeris was designed more or less on the same lines as the Nautical Almanac. To facilitate the publication of the Almanac a small printing establishment was started in 1836 which was the nucleus of the present Government Press.[59] The small printing press was subsequently enlarged. Printing machines were got down from England and a department for printing was opened. The first Government publication was the Anglo-Vernacular Calendar of Travancore for 1015 M.E (A.D. 1839-1840).[60] The printing establishment was then under the superintendence of Caldecott.[61]

58 Ibid., Lt. No. II.
59 V. Nagam Aiya, *op.cit.,* p.275.
60 *Ibid.*, p. 488.
61 Cover Files, 1841, Lt. No. I.

During his absence from 1838 to 1841 Sperschneider, a man of European education was employed as head assistant of the observatory. After the return of Caldecott from Europe, Sperschneider was acting as superintendent of the press, without an official appointment and with a very little payment. In the early part of 1840, when the Raja of Travancore ordered an increase in his monthly allowance, he was under the necessity of declining the offer then. But after three years, he felt that it was not an easy service with a meager payment, so he requested the Diwan as well as the Resident to increase his salary as promised earlier by the Raja and also for the separation of the press from the observatory.[62]

The British officer representing his Government at the court of Travancore under the title of Resident has always had a high influence in the decisions of the Travancore Government. As an enthusiastic observer and lover of science, General Cullen of the Madras Artillery, acted as Resident of Travancore till 1860.[63]

He suggested the Government of Travancore that the Press should form altogether a distinct and independent establishment from the observatory, which should be placed under the exclusive superintendence of Sperschneider. The Resident also suggested for the consideration of His

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62 Ibid., Lt. No. 2.
63 John Allan Brown (ed.), *op.cit.*, p. 6.

Highness a proportionate increase in the salary of the superintendent, as such an increase had formerly been authorized by His Highness but that he had been under the necessity of declining to accept it then.

He also regretted at the state of finances of the Government then, and stated that, he felt considerable hesitation in recommending any increase of charge, more especially after the observations of the Court of Directors upon the number of Europeans and East Indians in the service of the Travancore Government and their high salaries, but he pointed out that he himself had not suggested the employment of any additional individuals of these classes, but he had only suggested a small augmentation of salary to Sperschneider, as he felt that in doing this he only performed an act of justice to the individual.[64]

Accordingly, Sperschneider was assigned the post of a superintendent with an increase in his salary. The press was separated from the observatory and it became an independent establishment as it serves even today as the Travancore Government Press which publishes the Administration Report, the department reports, the statistical volume, the proceedings of the Legislature and the Readers and text books for schools and the Government Gazette, etc.[65]

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64 Cover Files, 1841, Lt. No. 3.
65 *Travancore Administrative Report*, 1942-43, p. 172.

Astronomical Observations

Caldecott obtained an assistant, a native trained under Taylor, astronomer at the Madras Observatory and other native assistants belonging to Travancore were practiced in the use of instruments and taught to perform the usual computations for reduction.[66] Three assistants were allotted to the Transit instrument for observing transit of stars to standardize local time, and three to each of the Mural circles.[67] John Herschel's[68] suggestion that hourly observations should be taken for twenty four hours together on four fixed days of each year, received due attention from the Madras observers.[69] Such observations were registered at the Madras and Trivandrum Observatories in December 1836, and January 1838.[70]

A large mass of observations, astronomical, magnetical and meteorological was accumulated and complete copies of them were forwarded to the Royal Society of London and to the Court of Directors of the East India Company. His observations comprised also the computed elements for the comets of 1843 and 1845, the solar eclipse of December 21, 1843 which he observed near the source of the Mahe River where, 'it just fell short of totality but offered a beautiful view of Baily's beads. All

66 Cover Files, 1857, p. 3.
67 *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p. 38.
68 Herschel belonged to a family of distinguished scientists of German origin. His discovery of Uranus was world famous as the first recorded discoverer of a planet and was the manufacturer of a large number of telescopes.
69 *Madras Journal of Literature and Science*, Madras, 1839, Vol. IX, p. 198.
70 C. D. Maclean, *op.cit.*, p. 524.

these astronomical and also other physical observations brought him recognition; already in 1840 he was elected a Fellow of the Royal Astronomical Society and also of the Royal Society.[71]

The observatory was often visited by His Highness, Vanji Pala Marthanda Varma and he used to stay at those places a few hours when ever he visited them. Caldecott, having been a great friend of His Highness took an interest in showing His Highness the use of the various valuable instruments lately procured and adjusted in the observatory, and in order to observe some of the early rising of the stars and planets, His Highness used to remain in the observatory sometimes very late after sun- set.[72]

Caldecott visited England again in 1846 in order to obtain if possible the aid of some of the scientific societies in publishing his observations, in this he did not succeed. He returned to Trivandrum in 1847 and continued to be in charge of the observatory till 1849. He died in his house at Trivandrum on December 17, 1849.[73] His Highness, Marthanda Varma felt the loss very deeply.

Before his death, Caldecott had impressed upon His Highness the necessity of procuring the services of a first rate astronomer from England, as his successor. He had also suggested to His Highness the establishment

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[71] S. N. Sen & K. S. Shukla, *op.cit.*, p. 389.
[72] P. Shungoonny Menon, *op.cit.*, p. 461.
[73] Cover Files, 1857, p.3.

of a Museum at Trivandrum. At the request of His Highness, the Resident General Cullen, who was a scientific scholar himself, and who took a deep interest in the affairs of the observatory, wrote to England and engaged the services of J.A. Brown, who soon arrived at Trivandrum and took charge of the observatory as its director.[74]

John Allan Brown, the successor wrote about Caldecott as-No person perhaps has been in a better position than myself to appreciate the extent of the work accomplished by Caldecott and his devotion to scientific pursuits; the energy with which he attacked the many difficulties that present themselves to scientific research in India is worthy of the highest praise, and I trust if the necessity of reporting what has, occupied myself may show that I have been obliged to differ frequently from my predecessor that this will not be considered as due to any desire to diminish the true value of his labours.[75]

After Caldecott's death, the Resident, General Cullen placed Sperschineider, the Superintendent of the press, in temporary charge of the observatory establishment with the approval of the Raja of Travancore. Cullen requested the Diwan of Travancore in his Lt. No. 66 dated January 10, 1850 that Sperschneider should be considered in permanent charge,

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74 P. Shungoonny Menon, *op.cit.*, p.461.
75 Cover Files, 1857, p.3.

until another astronomer is appointed, in order that he could enable to exercise a proper control over the servants, and be held responsible for the case of the establishment generally.[76]

The observatory was for a short time under the supervision of Sperschneider, till John Allan Brown joined as its director in 1852.[77] The preface to Brown's *Magnetic declination made at the Trivandrum and Agustia Observatories* testifies to the Maharaja's encouragement of science, and the following is an abstract of the same.

"His Highness Marthanda Varma the Raja of Travancore having named me for the direction of his observatory, I left Europe on the eleventh of November 1851, and arrived at Trivandrum on the eleventh of January 1852, when I took charge of the observatory".[78]

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76 Ibid., Lt. No. 4.
77 S. N. Sen and K. S. Shukla, *op. cit.*, p. 389.
78 Cover Files, 1857, p.3.

CHAPTER - 4

JOHN ALLAN BROWN AND THE AGUSTIA OBSERVATORY

The Trivandrum Observatory established in 1836 provided strong roots for the development of astronomical science in Trivandrum. Caldecott's efforts furnished the institution with new instruments and valuable books from England. A large mass of observations were forwarded to the Royal Society of London. After Caldecott it was Brown who had contributed to its development. In the astronomical history of Kerala, the Agustia Observatory occupies an important place. It was due to the interest of Brown that he devoted himself solely to magnetic observation. He examined the laws of terrestrial magnetism and the variation of meteorological elements as influenced by height in the atmosphere and selected Agustia on the Western Ghats as a destination for his experiments.

John Allan Brown, Fellow of the Royal Society, was appointed three years later as a Government astronomer to succeed Caldecott.[1] He was an eminent astronomer and had previous experience in the subject as he had

[1] *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p. 38.

been working for some years at the Makerstown Observatory in Scotland. He took charge of the Trivandrum Observatory in 1852.[2]

Immediately after his arrival he was assigned the duty of making an inventory of the instruments, books at the observatory and was instructed to forward a copy of it to the Diwan.[3] Accordingly the astronomer made a complete list of the instruments, books and also about the furniture in the observatory and a copy of it was forwarded to the Diwan on 21st August 1854.[4]

Erection of a Bungalow adjacent to the observatory for the accommodation of the astronomer

John Allan Brown resided in a bungalow now occupied by the Museum Department at Trivandrum. He found it difficult to perform his duties by residing at such a distance from the observatory. He felt that his assistants became lazy and dishonest as he could not keep a proper watch on them and pointed out that they had not made any discovery by which he could analyze them clearly.[5] It was quite necessary that the astronomer should always be by the side of his instruments, thus the Government provided him with quarters at the observatory hill.[6] In consequence he left the large bungalow and occupied the bungalow built near the observatory for the European assistant. This house was too small and he proposed in a

2 *Ibid.*, p. 39.
3 Cover Files, 1851-1864, Lt.No.1 and 2, C.No.6049, B.No.24.
4 Ibid., 1854, C. No. 15966, B. No. 13.
5 Ibid., 1853, C. No. 16484, No.674/1853, B.No.25.
6 *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p. 39.

letter to General Cullen dated 29th December 1852 that the Sarkar should aid him in building a more comfortable house. He pointed out to the Resident that the discomforts of the building he was then occupying and several advantages which might be derived from his residing at the new bungalow.

Further he proposed on December 29, 1852 to give up the use of an European assistant (previously sanctioned to Caldecott) for twelve months and that he is willing to take upon his own shoulders the additional work of an assistant in order to build an addition to the observatory which would enable him to perform his duties properly. At General Cullen's desire he wrote to him an official letter on 9th March 1853 requesting permission to use the European assistants pay for the construction of the additional building and offering to take upon him a greater amount of work during the year. He requested the Sarkar to supply him with the necessary wood and other materials and promised to render an account of the whole work when finished.

He received the Sarkar's permission to build an addition to the observatory on 28th March 1853 with the funds afforded by the salary of a European assistant and he began immediately to collect the materials and tools which he had obtained from the Sarkar and for which he had to pay the Sarkar for the materials.[7]

[7] Cover Files, 1865, C. No. 15967, lt. No. 12, B. No. 39 and also in appendix 2.

After the completion of the building, John Allan Brown wrote about the complete expenses and submitted to the Government an abstract of the expenditure through the Resident and said that the building was in a good state and that the mode of building was a subject of study and hoped to draw up a statement of his views and of the results of his experience in building in this country.

The abstract of the expenditure submitted to the government by the astronomer is as follows:

	Rs.	Ch	Ca
Teakwood, jack wood, Coconut etc. at Trivandrum Sawyers hire	512	4	3
Teak etc. from Sarkar as per account supplied by the Diwan May 30th 1854 up to that date	1117	11	9
Teak from Allepey and carriage	529	4	0
Total Rupees	2158	19	12
Glass, Brass hinges, bolts, screws, copper tacks, canvas tar, paint etc. from Bombay and Ceylon	1018	8	0
Carpenters, masons, stone cutters, smith painters and other coolies, men, women, boys and girls wages	1708	17	8
whitewash, sand, stones, tiles bricks, iron, oil, cadjan rope, dammar and various materials	1462	18	10
Total Rupees	**6348**	**7**	**14**

Brown requested the Sarkar to consider the circumstances and about the allowance to be made to him on account of the building which he is about to leave in the possession of the Government. The British Resident, Cullen submitted the astronomer's grievances through the Diwan for the consideration of His Highness the Raja and the Diwan conveyed the sanction of the Sarkar.[8]

The observatory occupied the summit of a small hill and as the visible horizon was many miles away all round, Brown desired to give as much architectural beauty to the observatory buildings and his new quarters, as possible.[9] The building had its greatest length in the meridian and is connected directly with the astronomical observatory. The plans, sections, elevations, molding and working drawings were all made by him. The whole building was terraced to afford facilities for certain classes of observations. The verandah columns were 14 feet high and 2 feet diameter at the base of the simplest Doric and the entablature was imitated from Inigo Jones on the church at convent garden (though Jusian) as a form best fitted to give shade and easily constructed. Several arrangements were adopted to give air and keep the building as cool as possible.[10]

8 Ibid.
9 *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p. 39.
10 Cover Files, 1857, C.No.16086, B.No.28, p. 25.

These buildings were completed towards the close of 1855. The observatory had three domes on its terrace and this formed a nice mark of identification of the observatory even from a great distance from the site. These domes could be observed by the mariners when they passed across Trivandrum on the Arabian Sea[11] and it formed for many years a pleasing landmark to sailors on this coast.[12] The longitude and latitude of the site of the observatory were re-determined during his time and the values arrived at were $76^\circ\ 59'\ 45''$ (76 degrees, 59 minutes and 45 seconds) East longitude and $8^\circ\ 30'\ 32''$ (8 degrees, 30 minutes and 32 seconds) North latitude of Greenwich, the barometer cistern being 195 feet above the level of the sea.[13]

Agustia Observatory

Brown was primarily interested in meteorology and particularly in terrestrial magnetism.[14] Therefore he later on devoted himself solely to magnetic observation for which he set up a special observatory at Agustia Malley within three years of his joining the Trivandrum Observatory.[15]

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11 *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p. 39.

12 *Travancore Information and Listener*, March 1948, Government of Travancore, p. 26.

13 John Allan Brown (ed.), *op.cit.*, p. 1.

14 Terrestrial magnetism means the magnetism of the earth which is also known as geomagnetism. It involves any topic pertaining to the magnetic field observed near the earth's surface, within the earth and extending upward to the magnetospheric boundary.

15 S. N. Sen and K. S. Shukla (ed.), *op.cit.*, p.389.

In 1840 not more than a dozen observatories in the world were making regular magnetic observations. Paris had been recording magnetic observations from as early as 1667. However, in India at the Madras astronomical observatory hourly magnetic observations were recorded from 1822 onwards. These were continued till 1861 when it was decided to record only two observations per day at suitable hours. The work was further reduced in 1875 when the bifilar magnetometer was the only instrument in use. The magnetic observations were finally discontinued at Madras in 1881.[16]

Brown started with a reorganization of the Department. He examined the laws of terrestrial magnetism and the variation of meteorological elements as influenced by height in the atmosphere. This, he thought, was possible only by simultaneous observations at two stations differing in height,[17] as he thought that observations should not be limited to a single station, but that the standard observatory should serve not merely for the determination of the laws and physical constants at one point, but also for the comparison and co-ordination of the laws depending on differences of height, of latitude and of longitude.[18]

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[16] *Hundred years of weather service (1875-1975)*, p. 150.
[17] *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p. 39.
[18] J. A. Brown, *op.cit.*, p. 6.

With this view he approached Government through Lt.General Cullen, the then British Resident at Trivandrum and obtained sanction in 1852 for the construction of an observatory at a suitable site on the Western Ghats.[19] The Western Ghats includes Travancore, Cochin and Malabar and comprises a strip of land of various widths, lying between the seas on the western side of India. It is undulating or hilly, covered with jungle of every description, from low bushes to the lofty forest tress. The climate is moist and comparatively cool. The Western Ghats is the range of mountains which extend from the valley of the Tapti to the Gap of Palghat about 800 miles and then after an interruption to Cape Comorin.[20]

Agustia Mallay

The Agustia Mallay is formed of granite, assuming in some places and in mass a stratified appearance, rising from the north (4000 feet high) to the summit in huge steps, like a mountain of trap, but in an unbroken slope to east and south, the angle of ascent being least to north (about 30° with the horizon), while to the west, upwards of 1000 feet from the peak, is a sheer vertical wall. The peak for about 1200 feet is chiefly bare rock, small tress and shrubs occupying the clefts and sheltered hollows on the north and north east sides. The summit of the peak is naked on all sides, excepting to

19 *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p. 39.
20 Edward Balfour, *Encyclopedia Asiatica,* New Delhi, 1976, p. 1065.

the south and south-east, where there is a strip of jungle. Consisting of trees rising to about 15 feet at the highest, low bushes, and a small cane, called vay by the natives, and bastard bamboo by the English.[21] Among the rugged peaks of the Western Ghats seen form Trivandrum, one is conspicuous for its height and its isolation.[22]

It is also tapering like a cone. This peak was considered by the ancient people of Travancore as the place made holy by the stay of the great sage, Agustiar, a savant physician, philologist, and theologian.[23] Agustiar was also, according to one of the many legends related to him, distinguished as a practical chemist. His principles were celebrated for their purity; his works on medicine and grammar are still cited, and some of the Christian missionaries of the south have found sayings of Agustia worthy of being repeated to the people.[24]

The Agustia Malley, about 22 miles east-north-east of Trivandrum, the highest mountain in the narrow chain of the Ghats, rising rapidly from the plains of Coromandel and Malabar, possessed the great advantage of being free from the effects of neighboring high table lands. The chief objection to this locality lay in its position, without roads, a day's journey from the nearest cultivated grounds, surrounded by forests inhabited by

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[21] J. A. Brown, *op.cit.*, p. 2.
[22] *Ibid.*, p. 485.
[23] *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p. 39.
[24] J. A. Brown, *op.cit.*, p. 485.

elephants and tigers. The construction of an observatory on this nearly inaccessible rocky peak presented considerable difficulties to Brown.[25] It was doubted also whether native observers, accustomed only to the climate of the plains, could live, or could be induced to try to do so, on a mountain top which for months of each year remains buried in cloud. Its summit was 6200 feet above the level of the sea; its peak was isolated, as there was no plateau nearer to it.[26]

Origin of an observatory at Agustia Mallay

John Allan Brown wrote from Europe, in July 1851 to Lt. General Cullen, on the subject of this observatory even before his arrival. He had previous experience on terrestrial magnetism between Makerstown Observatory and the Cheviot Hills in Scotland. He had communicated his ideas on the subject to a number of scientists in Europe, and all agreed with him in considering the objects he had in view of the highest importance to science.

On the 23rd of March 1852 he brought the subject before the Sarkar in an official form, and on the 30th, April he received the official sanction for the erection of the observatory on the Ghats.[27]

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[25] *Ibid.*, p. 6.
[26] *Ibid.*, p. 7.
[27] *Ibid.*, p. 486.

Construction of the Agustia Observatory

It is built in a small jungle lying on the south-east corner of the peak; the plan is rectangular, 55 feet by 18. The western part has two stories, from the upper storey a staircase leads outside the roof to the small platform on the ridge of the tower.[28] In reaching this lofty site, paths had to be cut through jungles occupied by wild elephants, and there were delays owing to laborers absconding from fear and cold.[29]

After encountering considerable difficulties, the construction of the observatory at this site begun in 1854 and it was completed by the end of 1855. The structure of the building was all in wood,[30] on account of the facilities in obtaining that material and the necessity for economy[31] and as it was intended for magnetic observations it was to be iron free.[32]

About 2300 feet below the summit to north west, the wood was taken to pieces, carried up to the top, and was rebuilt under the superintendence of John Allan Brown in the beginning of 1855, within the small jungle, and in such a position that it was sheltered, as far as possible from the monsoon winds. The pillars were built of granite stones obtained in digging for the foundations; the lime for cement was brought from the

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28 *Ibid.*, p. 495.
29 C. D. Maclean, *op.cit.*, p. 523.
30 *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p. 40.
31 S.Raimon (ed.), *op.cit.*, p. 56.
32 Travancore Information and Listener, *loc.cit.*, p. 26.

seashore on coolie's heads. Each pillar was founded on the granite, and the flooring and floor beams were kept at a sufficient distance from them, so that the pillars were thus far independent of the building. The corner posts, with a section of eight inches square, were inserted deeply into the ground betwixt the decaying blocks of granite resting under the soil.[33]

The observatory at Agustia Malley is approximately in Latitude 8° 38' N, Longitude $5^h\ 9^m\ 15^s$ E and the height above the level of the sea: 6200 feet.[34] The temperature at night would be about 45°F, and during a great part of the year the hill would be covered by clouds, and stormy conditions would prevail.[35]

Instruments

John Allan Brown's experience while directing the Makerstown Observatory in Scotland had suggested changes in the instruments and method previously employed in connection with terrestrial magnetism, and before leaving England he ordered two series of instruments to be constructed by Adie of London according to his instructions. These instruments could not be established in the observatory till the end of

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33 J. A. Brown, *op.cit.*, p. 3.
34 *Ibid.*, p. 495.
35 *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p. 40.

1853.[36] After its arrival one was adjusted by him in the Trivandrum Observatory, and the other in the Agustia Observatory.[37]

The instruments received by Brown in November 1852, unfortunately from a precaution is taken to keep the magnets in dry air by means of chloride of lime, the whole of the magnets and the metallic mirrors were rendered useless. A new set of magnets and glass mirrors were received by Brown in July 1853.[38]

The other instruments are the three magnetometers, the declinometer and its telescope pillar, the bifilar and its telescope pillar, the balance and its telescope. The telescope pillars are kept in the computing room with the slides in the wall, allowing the mirrors to be seen from these telescopes, the clock pillar, the clock with mercurial pendulum by Johnson, London, a barometer, the thermometers are placed, were the strong current of air generally passed round the corner of the building. There is also a fire place, the sleeping closets for the observers from the eastern part of the building.

The instruments are by Adie, and are exactly the same construction as those in the observatory at Trivandrum, with the exception that the bifilar is covered by a conical box of wood instead of its glass receiver, which was

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36 J. A. Brown, *op.cit.*, p. 6.
37 *Ibid.*, p. 7.
38 Cover Files, 1857, p. 27.

smashed on the voyages from England to Trivandrum.[39] The Government of Travancore had sanctioned the following sums since the arrival of John Allan Brown as the Director of the observatory and paid to him for the following expenses.

		£
-	Books for instruction of assistants	– 40
-	Repaid to Brown on account of instruments ordered on his own responsibility before leaving England	– 300
-	For ground and other thermometers, barometers, clocks sanctioned since his arrival	– 80
-	Books for the library	– 60
-	Repaid him the expenditure till June 1855 on account of the building of the Agustia Observatory	– 170
-	Sanctioned a monthly allowance for batta to the assistants and the minor expenses at the Agustia Observatory	– 7
-	And for an annual allowance for periodicals for the library	– 20

A sum of twenty five rupees or nearly £ 2.10 is allowed monthly for the minor expenses of the observatory. The following payments are frequently in Sarkar rupees which are of less value than the rupees of the East India Company.[40]

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[39] J. A. Brown, *op.cit.*, p.495.
[40] Cover Files, 1857, p. 78.

Observers

The assistants in the observatory establishment were arranged into three sets of four men each, depending as far as practicable on caste for facilities in their cooking and other arrangements- the first set of Syrian Christians, the second of Brahmins and Sudras, and the third of Roman Catholics. Each set, it was arranged, should occupy the mountain observatory for three months; the position of the observers was much better than it had been before.[41]

Observations

The observations made during the years 1852 and 1853 at Agustia were either of an inferior kind, or the series were much broken up by the repairs and alterations going forward in the observatory. John Allan Brown determined all the constants requisite for reductions, except in the case of the balance magnetometer, where the magnetic dip is required; this, he was not been able to observe satisfactorily for want of a proper instrument and needles.

The temperature coefficients of all the magnets were determined by hot and cold water experiments in the usual way, with the aid of an instrument which he formed chiefly from a reflecting circle. They have also

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[41] Ibid., p. 496.

been determined by his own process of comparison of the usual observations at different temperatures. Errors in observations at the Trivandrum Observatory are generally checked by the observations at Agustia, and vice versa.[42]

First Series of Observations, 1855-1859 at the Agustia Observatory – Ordinary observations

These observations begun on 1st July 1855, continued hourly till July 1858, after which it was made during the day hours only, till the end of March 1859. The instruments observed were Adie's declinometer, Adie's bifilar, and Adie' balance magnetometer, the barometer and attached thermometer, dry and wet bulb, ground and other thermometers. Direction and force of wind, species of clouds and amount of cloud surface, evaporation of salt water, with temperature of water, rainfall, etc., were also observed,- all the observations being made simultaneously with those at Trivandrum.[43]

The time was communicated from Trivandrum to the Agustia Observatory by means of mirror flashes when the sun shined, at previously agreed instants in the morning, as Brown had practiced before (in 1847) between Makerstown Observatory and the Cheviot Hills in Scotland.

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42 Ibid., p. 499.
43 Ibid., p. 504.

During the cloudy weather of the monsoon of 1856 the clock stopped. To be prepared for such an accident again, Brown sent a clock, by Bryson of Edinburgh, to the mountain. He also had the clock at the mountain cleaned, the stoppage being chiefly due to the smoke from the fire. As he found that the mirror flashes could not be given at all seasons, he proposed to fix a portable transit, of Englefield's construction to a post near the observatory, so that the observers would be able to determine their time directly.[44]

Second Series of Observations, May 1864 to February 1865 - Re-building the Observatory

Before the final observations were collected, the observatory at the peak had to be repaired in 1863 and a few more instruments were also added then.[45] Brown was occupied with the cutting and sawing of timber and with the necessary carpentry work at Potheamallay the nearest point to Agustia peak where sufficiently good timber could be obtained.[46]

To have the Agustia Observatory thatched was another matter. It was necessary to get the Diwan to give orders to the Tahsildar of Nedumangad (the district west of Agustia); the latter should then give orders to the Adikarries of Aryanadu and Uzhamalakkal (the nearest proverticars), whose duty it was to procure the requisite number of coolies to proceed to the

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44 Ibid., p. 496.
45 *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p. 40.
46 S.Raimon, *op.cit.*, p. 56.

mountain, cut grass several thousand feet below the summit, carry it up, and then thatch the observatory.

On the 16 April 1862, Brown again addressed the Diwan, restating the objects of the Agustia Observatory, its original construction under many difficulties, at his own expense in the first instance, the necessity of another year's observations on account of errors due to circumstances connected with the position of the observatory, -circumstances whose effects could not be at first foreseen; and the Sarkar's sanction already granted for another year's observations.[47]

At the same time Brown requested the Sarkar to sanction £ 30 for the small instruments made in Lamont's[48] atelier at Munich, according to his own method, which Brown had requested Lamont to favour him within 1861; with these instruments, Brown hoped to avoid some of the errors caused by the previous instruments. He also requested the Sarkar to sanction a monthly allowance of seventy rupees for twelve months, on account of additional pay to observers, and etc., during the year's observations at Agustia and also of three hundred and fifty rupees for certain apparatus which had arrived at Ceylon.[49] The official sanction of the sums required for another year's observations was communicated to Brown

[47] J.A. Brown, *op.cit.*, p. 506.
[48] Dr. Lamont, the astronomer Royal of Bavaria, Munich Observatory.
[49] Cover Files, 1862, No. 14, C. 16475, B. No.34.

by the Diwan on 5 September 1863.[50] Brown considered that the first thing to be done was to complete the observatory for the reception of the instruments by the erection of stone pillars in proper positions. This was done with as much care as possible, separating the bases from the surrounding soil by small trenches so that the action of the wind on the corner pillars of the building might be as little felt as possible.

After much trouble in many ways, he succeeded in completing the building and adjusting the instruments, ascending daily 1,200 feet from the small wooden bungalow in which he lived (5,000 feet above the sea) reaching the top about eight a.m. and descending at sun set, the adjustments were completed on the 18th of May at four p.m.[51] The cost of the observatory amounted to nearly Rupees 15,000 per annum[52]

The observations begun on the 20 May 1864 by three observers, they were continued by other sets of three observers, who relieved each other at intervals of three months till the 28 February 1865, when the series of observations ceased due to the following reasons:

1. The climate at Agustia was very damp; the sky is obscured by clouds and rain, so that observations could not be made frequently.

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[50] J. A. Brown, *op.cit.*, p. 509.
[51] *Travancore Administration Report 1859-60*, p. 27.
[52] V. Nagam Aiya, *op.cit.*, Vol. IV, New Delhi, 1898, p. 531.

2. The instruments are very costly and some of the instruments got damaged during transportation from England to Trivandrum. The errors in the instruments also obstructed from further observations.

3. The transportation to and from the Agustia Observatory became very difficult and much worse during bad weather conditions.

4. Difficulty in meeting the expenses of the observatory and inadequate staff are the reasons for stopping the observations at Agustia.

Brown visited the observatory in January 1865, for the purpose chiefly on readjusting the induction inclinometer. The instruments were removed in March 1865, and Adie's bifilar and balance was again adjusted on the pillars they had previously occupied in the Trivandrum Observatory.[53]

Besides the magnetical observations obtained at the two observatories, others especially of magnetic declination, were made simultaneously during short periods at different stations in Travancore, as nearly as possible on the magnetic equator, ninety miles north of Trivandrum, and forty miles to the south observations connected with

[53] J. A. Brown, *op. cit.*, p. 509.

meteorological[54] questions were also made simultaneously to the east and west, and about 5000 feet below the Agustia peak, on the peak itself, and at Trivandrum; while on one occasion observations were made hourly during a month at five different stations, varying gradually in height from the Trivandrum Observatory (200 feet) to 6200 feet above the sea level, in which fifteen observers were employed.[55] The number of observations made daily (expect Sunday) at Trivandrum and Agustia amounts to upwards of 1000; from these nearly 700 corrected results were obtained.[56]

Some idea of the work done in the observatory may be gathered from the following description by the Director of the transactions of the Department, in 1039 M.E. (A.D. 1863-64).

1. The usual work of the observatory was continued, consisting of observations in magnetism and meteorology made hourly, the number yearly being upwards of (200,000). These have been reduced, partly corrected and also in part tabulated.

2. The monthly abstracts of observations were written out and computations of daily and hourly means were performed.

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54 Meteorology is the science of the atmosphere. It studies the earth's atmosphere and its changes: the change in wind, rainfall, temperature, pressure, humidity etc. by means of instruments like thermometers, barometers, hydrometers, pluviometers, tidal gauges and so on.

55 J. A. Brown, *op.cit.*, p. 7.

56 *Ibid.*, p. 499.

3. Differences for meteorological means were obtained.

4. Effects of the moon upon the atmospheric pressure were obtained from means during the years 1853-57 and 1857-64.

5. Tables of means of meteorological observations were made out.

6. Differences of hourly observations of the Bifilar and Unifilar for the years 1856-1864, for the moon's hour angle and for different declinations of the moon were computed.

7. Calculations of the temperature co-efficient of balance magnetometer were made.

8. Calculations of a more accurate temperature, coefficient of bifilar from differences of daily means, for the years 1857-64 performed.

9. Reductions and entries of daily and hourly means of evaporation in and out of the shade, were made, as well as for the temperature of the water, during the years 1857-64.

10. Daily and hourly sums of velocities of wind for the different points of the compass with resolved velocities to the cardinal points were obtained for the years 1856-1864.

11. The daily and hourly positive and negative sums and means, positive and negative numbers, mean differences, and etc., of the hourly differences of magnetic declination were computed for the years 1854-1864.

12. Calculations for the moon's effect on the magnetic declination for the year 1860-1864 were obtained.

13. Transit observations were made chiefly for the time required for the observatory, and for the fall of ball or flag.

14. Tables for the Trivandrum Almanac were published.

15. The Director was occupied during nearly two months at Agustia.

   i. In super intending the repairs of the observatory there.

   ii. In observations for the magnetic elements of magnetic declination, horizontal force, and inclination at different heights.

16. The observations were made frequently at a height of about 4900 feet several times on a summit of Agustia (6200) and twice at heights of 1000 to 1500 feet, exclusive of the observations at Trivandrum, before and after, at a height of 200 feet.

17. In connection with the observations at the standard station (4900 feet) a short base line was measured and the height of the station on the peak above the standard station was determined trigonometrically. Observations also were made for the depression of the horizon from the standard station as well as for the latitude and time.[57]

Native visitors

Natives were allowed to visit the observatory, so as to encourage as much as possible the desire for information, Brown fixed on the hours from 10 a.m. to 4 p.m. daily (excepting Sundays), as the time during which the observatory was opened to them. The number of visitors between 24 September 1852 and 1 January 1857 were 1121.[58]

New Discoveries at Madras observatory

At about the same time, the Madras Observatory participated in observations and discovery of new planets, minor planets and comets, especially when such are invisible to European astronomers. The asteroids Asia, Sappho, Sylvia, Camilla and Vera and the variable stars Y Virginis, U Scorpii, T Sagittari, Z Virginis, X Capricorni and R Reticuli were all first discovered at Madras either with the transit instrument or by the equatorial

[57] *Report on the Administration of Travancore for the year 1863-1864 A. D,* p. 26.
[58] J. A. Brown, *op.cit.*, p. 500.

instruments.[59] Asia, one of the minor planets was discovered on 17 April, 1861. It is so named in consequence of its being the first discovery made in this quarter of the globe. It was Pogson, the Astronomer of Madras Observatory from 1861 to 1891 who had explored new areas of observations.[60] The discovery in 1867 of the light variation of Reticuli by C. Raghunatha Chary, the Assistant Astronomer is perhaps the first astronomical discovery by an Indian in recent history.[61]

Errors of instruments

Some errors appeared unfortunately to exist in all the instruments at the Trivandrum and Agustia Observatory, which could not be accurately determined. In the transit instrument at the Trivandrum Observatory, the error was supposed hypothetically to be due to flexure of the tube, and a correction varying with the cosine of the zenith distance was applied. No hypothesis could be made for the errors of the circles, latterly an unequal expansion of the rock on which the observatory is built was proposed and spirit- levels were placed on the circle piers, to determine its amount.

From a large number of observations Brown found out that the readings of a spirit level, and the apparent height of one end, vary with the

59 Priyaranjan Ray and S. N. Sen, *op.cit.*, p. 262.
60 *Report on the Administration of the Madras Presidency 1874-75*, Tamil Nadu Archives, p. 487.
61 Priyaranjan Ray and S. N. Sen, *op.cit.*, p. 262.

hour of the day (i.e. temperature). For all these reasons, Brown decided to avoid the use of the spirit- level in the determination of the errors of the transit instrument. He used the following practical method for the determination of the flexure of the telescope. A small plane mirror with adjusting screws is to be fixed to the object end of the telescope, so that when the object glass is lowest the image of the middle wire may be seen reflected from the mirror, as in the observations by reflection from a basin of mercury for the collimation and level errors, the distance of the middle wire from its image determined by the micrometer wire covering the latter, the telescope should be turned round into all the different positions it can occupy. If the optical axis varies, either by lateral or vertical flexure, the amount will be obtained at once by measurements of the varying positions of the image of the vertical and horizontal wires.[62]

The Mural circles

The granite pillars had not their faces built perfectly in the meridian; the consequence of this error was the necessity of raising the microscopes on one side further from the face of the pier than on the other side. The late Taylor, astronomer to the East India Company at Madras who had been invited to Trivandrum by Caldecott for the purpose, fitted up and adjusted the mural circle by Troughton and Simms; unfortunately he employed

[62] Cover Files, 1857, p. 9.

plates of teakwood to raise the microscopes from the granite. This example was followed in the adjustment of the circle by Jones, in the former instance however, the microscopes on one side only were so raised while in the case of Jones circle the suspending lever not having been properly placed it was necessary to raise all the microscopes from the surface of the pier.

This mode of arranging the microscopes had produced considerable error and that the hygrometric action on the teakwood in such a climate as this would suffice to explain all the irregularities found in the observations of these instruments by Caldecott, as an evidence of this Brown determined that Troughton and Simms circle gave better results than Jones which can easily be explained by the fact that three microscopes of the former instrument are fixed directly to the piers. Shortly after his arrival in India the shutters of the observatory being out of repair some drops of rain had fallen on the microscopes of Jones circle and a sudden change of 4" took place in the readings by reflection for the nadir, Brown found on examining a microscope that had been shifted that it rested on a teak plate. Brown thought that it is quite probable however, that other sources of error existed. In order to put those instruments in a proper state for observing, the granite piers should be re-cut and the instruments readjusted.[63]

[63] Ibid., pp. 10-11.

The Equatorial

The building for this instrument had been condemned as insufficient before Brown's arrival at Trivandrum, the walls were cracked and the terrace leaked during the monsoon, so that he put a temporary thatched roof over the whole, dome and terrace, during that season. He found that the position of the instrument was very exceptionable; the base of the dome was on the same plane with the upper surface of the north pillar so that several degrees near the horizon were lost. The level of the terrace of the building was only five feet above the floor of the transit room and great part of the sky from east to south east could not be commanded. Upon examination he found that by slightly altering the arrangement of the pillars, the equatorial might be placed under a dome on the tower where the whole hemisphere could be examined. Considering the state of the building, the planks supporting the terrace being quite rotten, and the rain pouring in at every corner, he determined to remove the instrument, in doing this he had to regret a slight accident to the tube, the object glass, eye tubes, and all the details being taken down, the counter poise was unchanged and removed, after which the tube which proved heavier than he had supposed turned suddenly round and in spite of the resistance by him and an assistant it fell with some force on the arms of the large observing chair. Fortunately the damage done was confined to two depressions of slight depth on the

tube which were so well beaten out by work men accustomed to such work that the form of the tube was not at all affected and the accident could only be known by the point cracked off the tube. The instrument was ready for use some months ago but he had not adjusted the instrument in its new position then.[64]

Similarly there were errors in the meteorological observatory and alternations were made by Brown with the instruments such as Declinometer and with the new Declinometer, Bifilar magnetometer, Adie's Bifilar, the Balance magnetometer, the Balance magnetometer by Adie, the inclinometer, Absolute intensity magnetometer, Electrometers, and self registering magnetical instruments.

Errors in the magnetical observations

Early in 1864, Brown had proposed to commence the last series of magnetical observations to be made at the Agustia Observatory, with a set of Lamont's small instruments, which he believed were more likely to give satisfactory results than the set previously employed. He however, before leaving, tried at Trivandrum one of the simplest of all, the declination magnetometer. The observations with this instrument were compared with those by the true declination magnetometers already in the observatory,

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64 Ibid., pp. 11-12.

when to his surprise; he found that the results were so unsatisfactory, that for the nice objects in view the instrument was worthless. He attributed the errors to the very small weight suspended, and to the great effect of the humidity in the silk cocoon fiber by which it was suspended, and he began a series of experiments, in which the threads were reduced to their ultimate fibers and reconstructed, which occupied him nearly two months. The difficulty of seeing and manipulating these fibers, as fine as spider threads, was very great, and, as he found ultimately, very hurtful to the sight. It was evident that he could not depend upon the small series of instruments altogether, and accordingly took down an Adie's Bifilar and an Adie's Balance magnetometer adjusted as duplicates in the Trivandrum Observatory, and after adjusting Lamont's intensity and a Lamont's induction magnetometer in their places, he proceeded to Agustia on the 3 March 1864.[65]

The instruments adjusted at Agustia were Adie's Declination Bifilar and Balance Magnetometers, the same series as had been erected previously on the same spot, the first and third having large glass shades, the second having a newly arranged box. Also Lamont's small series of declination horizontal force magnetometer and induction magnetometer. The mercurial pendulum clock was also put up on a stone basement and with back pillar,

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[65] *Report on the Administration of Travancore for the year 1859-1860*, p. 27.

and a pillar was built to the north of the observatory for a portable transit instrument employed both in the meridian for transits and out of it for altitudes.

On the 2 March 1864, the day before his departure for Agustia, he received the instrument made in Lamont's atelier at Munich Observatory and forwarded to Agustia. The Sarkar sanctioned a sum of 30 £ in payment of this instrument and its carriage from England overland to Madras.

The instrument was tried by him at Agustia. The instrument consisted of a cubic weight suspended by two fine wires, the weight has mirrors on three vertical faces, below, and a lever is suspended by a single wire with a mirror at each end of the lever, the single wire being attached to the top of the weight. By a simple arrangement this lever can be turned round through 180 degrees by means of agate acting on the polished needle end of the lever which thus forced the weight through an angle of nearly 90 degrees.

This action of the agate against the lever is an imperfection since the smallest possible amount of friction at the end of the experiment must enter into the equation of equilibrium and diminish the accuracy of the result and this the more that the variations of forces to be measured are small. He noted in an official letter to the Diwan upon the subject dated 21 March

1864, that he had devised a plan by which the source of error might be completely eliminated, namely, by using a magnet in place of the lever, and producing the turning movement by means of a large magnet placed in the proper position, without the instrument, for this end. This method can be made free from all errors due to the action of the Earth's magnetism at the beginning of the experiment.[66]

The next imperfection is that due to the different modes of suspension of the lever and weight (unifilar and bifilar) from this cause while a given twist of the single wire produces at the beginning of the experiment an equal or nearly equal movement of the weight relatively to the lever, at the end of the experiment the smallest possible additional twist of the wire produces an excessive movement of the weight (from fifty to hundred times the additional angular twist of the wire). This imperfection he proposed in the letter already alluded to, to obviate by suspending the lever also by two wires, when a single relation to the weights of lever and cube to the lengths of their respective wires, ensures equal movements throughout the experiments.

The instrument as received by him was also incapable of measuring quantities of angular movement sufficiently small, owing to the position of the telescope and to the glass scales not having been graduated with

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66 *Ibid.*, p. 28.

sufficiently small divisions. He endeavored to put the instrument into a state for observation at the Trivandrum Observatory by the above mentioned changes and for its perfect action he considered that the instrument must be reconstructed.[67]

Invention of Gravimeter

In the year 1866, the Government of Travancore paid £ 400 to enable him to construct a Gravimeter, which he had invented for the use at Trivandrum Observatory. This instrument was used for measuring the force of gravity on the earth's surface.[68]

Brown had seen a passage from the Reader, 17 September 1864 (p. 361, second column) under the heading of pendulum observation in India. In it John Herschel has recommended the employment of Brown's instrument (the gravimeter) in connection with pendulum experiments, which the British Government proposed to have made over India and in connection with which the Government had sought the opinion of the most eminent scientists in Britain. Brown's opinion was that, there could be no doubt as John Herschel said that with this instrument observation could be made within an hour which required many days by the pendulum and by

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[67] *Ibid.*, p. 29.
[68] Cover Files, 1865, C. No. 151, B. No. 38.

this he trusted that the Sarkar would enable one to put the instrument in such a state as would make it fit for the objects in view.

He mentioned in connection with the use of the instrument that when carrying out a magnetic survey of Travancore in the beginning of 1860, he found that the line called the Magnetic Equator was not a fixed line, but a belt within which the magnetic dip varied from north to south in an extra ordinary manner, and that in the country betwixt Cochin and Alleppey which as is well known is a flat of sand, mud and backwater without any mountain masses likely to produce magnetic derangement. He was induced to ask the question whether there might not be something in the crust of the earth below these sands likely to produce the variations alluded to, and whether an instrument like that now constructed might not enable him to answer this question. With reference to this Brown noted that Lamont, Director of the Munich Observatory, informed him some time ago that he believed that he had found some relation betwixt irregularities in the magnetic lines in some parts of Europe and of the attraction of gravity.[69]

His Highness Martanda Varma who had appointed Brown died in 1860. The following is an abstract from Brown's *magnetic declination made at the Trivandrum and Agustia observatories* about the Maharaja. "His Highness Martanda Varma, to whom I owed my appointment, died in

[69] Ibid., pp. 29-30.

1860. His Highness was a warm hearted gentleman whose death was regretted by all who knew him. His knowledge of science, though greatest in Chemistry, gave him a personal interest in the observatory, and he was ever prepared to accept any proposition likely to aid the work done in it. I shall never cease to entertain with the liveliest feelings his Highness memory".

About his successor, Rama Varma, Brown regards that "His Highness Rama Varma, the present Maharaja, has always shown the greatest readiness to forward my views with relation to the work of the observatory. His desire to support this institution, as well as every object which has the advancement and prosperity of his country in view, is well known. I owe especially to his Highness my warmest thanks for the kind consideration which he ever gave to my suggestions".[70]

Closing of the observatory

In 1863, Denison, Governor of Madras, paid a visit to His Highness the Maharaja at Trivandrum; he did the honor of calling upon Brown twice and had conversations with him on the subject of the observatory. Denison asked his written opinion on the whole subject; and after he was made acquainted with the whole difficulties of the position, even with the aid of

[70] J. A. Brown, *op. cit.*, p. 8.

British residents who looked favorably on the work of the observatory, he communicated his conclusions to His Highness the Raja.[71] Denison expressed his opinion as to steps which it would be advisable that His Highness the Raja should take with regard to the maintenance or abolition of the establishment.[72]

He said that on the information he had received from Brown, he would recommend the purchase of a meridian circle and an equatorial with an object glass of seven or eight inches diameter, if the observatory were to be maintained,[73] but his opinion is that though instruments of an expensive character, such as two mural circles, a transit clock were purchased and used for sometime for astronomical observations, yet owing partly to the error of the instruments themselves, and partly to the mode of mounting the observations he had not been of that degree of exactitude as to make it worthwhile to reduce them, and by printing to place them on record as data, upon which dependence might be placed. He was doubtful, whether any care and attention which might be bestowed on remounting these instruments and on detecting instrumental errors would ever make them available for correct observation besides this as there are three meridian

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71 *Ibid.*,p. 526.
72 Cover Files, 1863, C. No. 16103, B. No. 35.
73 J. A. Brown, *op. cit.*, p. 526.

instruments, more than one observer would be required to make the best use of them.

Secondly, having difficulties of climate (clouds and rain), as he was informed by Brown that the climate of Travancore is very damp, that the sky is often obscured by clouds, so that observations cannot be made very frequently.[74] So he thought that the existence of an astronomical observatory at Madras, and an observatory at Trivandrum would not seem to be required. Denison concluded that the wisest course would be to allow Brown to complete and publish his observations and to close the observatory[75] altogether- that to maintain such an establishment as would be required, would entail an expense which would press upon the finances of the country, and the money saved by closing it might be expanded with greater benefit both to the Government and the people, by which the material resources of the country would be developed.[76]

Thus it may be summed up with the following reasons for closing the observatory.

1. The astronomical instruments in the observatory have become so far out of date, that observations made with them, cannot possibly be expected to compete in point of accuracy with those made

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[74] Cover Files, 1863.
[75] J. A. Brown, *op. cit.*, p. 526.
[76] Cover Files, 1863.

elsewhere with instruments of recent construction. To procure a new set of instruments would of course prove exceedingly costly, and the Sarkar might well pause before incurring so great an outlay in the presence of much nearer and more urgent demands on the public Treasury.

2. It is also to be recollected that the geographical positions of the Madras and Trivandrum Observatories do not differ so far as to make it probable that two institutions so closely situated would be able to effect more for science than one.

3. A good proportion of the funds saved by the Sarkar by closing the Trivandrum Observatory would, it is hoped, be cheerfully devoted to the further propagation of a sound and liberal education among the subjects of this principality.[77]

With the retirement of Brown there was not available in the state any competent scientific head to supervise and guide the institution. For these reasons, the Government resolved to abolish the observatory in 1040 M.E. (A.D. 1864-65).[78]

The Travancore Government, in concurrence with the opinion of the Governor of Madras, decided on closing the observatory as soon as Brown

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77 *Report on the Administration of Travancore for the year 1862-63*, p. 47.
78 General Section, 1928, File No. 349, B. No. 234.

had completed the series of observations which he considered as necessary for his purposes.[79]

Most of the instruments were offered for sale and some have been sold except the transit, the equatorial and one or two primary instruments which were kept up to ascertain local time and to aid educational purposes and so on. Certain magnetic observations are also carried on, to last for a few years more. For these purposes a small establishment of native observers was maintained. Brown was engaged in printing observations and a limited number of copies would be issued for the benefit of the scientific world.[80]

In this connection the following remarks of Brown may be interesting:

"The establishment of an observatory in Travancore was the setting up of an intellectual pharos amidst an ocean of mental darkness, which showed to other nations the desire of the prince to enroll his country and himself in the great army of progress, and which directed the thoughts of a people lying in ignorance and superstition to something higher than their daily wants, for 'Man shall not live by bread alone'. It was a first and great

[79] J. A. Brown, *op.cit.*, p. 526.
[80] *Report on the Administration of Travancore for the year 1864-65*, p. 52.

step towards every species of moral and intellectual advancement, and a pledge that other steps would follow".[81]

"I believe it will be seen from the preceding report that such an institution with a scientific chief may be useful directly to the material interests of the country in which it exists, and therefore that it was a narrow view of the way to give prosperity to Travancore to propose its abolition".

"While every attention had been paid to my personal wishes in connection with the work I desired to accomplish, I could not help regretting that an institution which might still have done much for science in other hands should be closed, but the difficulties which I had to overcome were so great that it was not improbable my successor might fail to cope with them even as well as I had done, and, in such a case, I had already said in my letter of 16 September 1863, it was much better to close the observatory".[82]

By these efforts, Brown was able to show the scientific world the importance of carrying on such observational work at Trivandrum. His personal guidance and supervision of the work had to be discontinued after 1865, when he left for England.[83] Although the Travancore Government had decided to close the observatory on his departure from Trivandrum for

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81 J. A. Brown, *op.cit.*, p. 533.
82 *Ibid.*, p. 526.
83 *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p. 40.

Europe in April 1865, yet he was fortunate enough to obtain a continuation for six years of a limited series of observations, this continuation he owed chiefly to the recommendations of Denison, the Governor of Madras, who had supported his views and his desire for the additional series, the Sarkar expressed its readiness to sanction the small sum required annually for the establishment proposed by him.[84] Brown returned in 1866 and continued in service till 1869. This record of pioneer work of Brown from 1852 to 1865 led to results of the greatest importance in magnetism and Brown's speciality in the field is evident from the fact that his work and results are quoted even today in papers on magnetism.[85]

When in service, he readily undertook to receive and discuss the observations thus to be continued under his direction and to provide instructions to his two best assistants, KochuKunju, head assistant, and by Kochavaray.[86] The former had charge of the magnetic department, under his directions during nearly two years of his absence from Trivandrum, and he was quite capable of judging in all cases where judgment was required, having assisted him in many adjustments.[87] The series of

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84 J. A. Brown, *op. cit.*, p. 7.
85 *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p. 40.
86 J. A. Brown, *op.cit.*, p. 7.
87 *Ibid.*, p. 528.

observations made at the observatory were sent to Brown in England for incorporation into his book.[88]

These series of observations were sanctioned for six years only, but a discussion made by Brown of the observations up to 1870, which was communicated to the Academy of Sciences of Paris, gave results of so much importance, that the desire which he had expressed to Ballard, the British Resident since 1869 for their continuance received his support, and the Travancore Government allowed the function of the observatory.[89]

It was in 1874, that KochuKunju, head assistant of the observatory passed away and Brown regretted much for this death and to his honest services to the observatory. Brown requested the Sarkar to grant a pension to his widow and family. To his place was appointed Kochavaray who had been recommended by Brown as a quite spirited man to carry on the observations as before and he had also promised to give him instructions whenever they might be required. Brown also requested the Sarkar to provide the same salary allowed to KochuKunju to Kochavaray.

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[88] *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p. 40.
[89] J. A. Brown, *op. cit.*, p. 528.

Retirement of Brown and the Remuneration for printing the observations

Hundred and fifty dollars was paid to Brown as passage money back to Europe and a life pension of four hundred and twenty dollars was sanctioned to him. Sixty dollars per annum was paid as his remuneration for publishing the observations and when the complete work is published it was to be added to his life pension.[90] The payment of fifty dollars per annum for a computer which was originally allowed for four years was later on extended to one more year i.e. from 1 May 1865 to 1 August 1870 from which date it was discontinued. Brown received an amount of four hundred and eighty dollars a year after his retirement from the observatory.[91]

The work of printing and publishing was given to the Neil and Company known as the Book and Law Printers to M.M. Stationery Office for Government Printing in Scotland, established in 1749 at Old Fish Market, High Street, Edinburgh. They were the printers of the Encyclopedia Britannia, of the Edinburgh astronomical observations, to the Royal Society of Edinburgh, etc.[92]

Owing to the order in which the computations had been made, and to the delay in publication, it has been found preferable to devote the first

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[90] Cover Files, 1865.
[91] Ibid., *1865-79*, C. No. 6075, B. No. 39.
[92] Ibid.

volume wholly to the magnetic declination. The observations connected with this subject, made, within the years 1852 to 1865, with different instruments, which have been reduced, amount to upwards of three hundred thousand; from 1865 up to 1870 nearly forty thousand observations of declination, have been made. The numbers given should in reality be increased by one third, as two observations of Grubb's declinometer were made at each hour.[93] The bifilar and unifilar observations made at the base of the Agustia peak and at Trivandrum during the years 1865-1869 were dispatched to Allan Brown. The Transit of Venus was observed in the year 1874 and notes of the observations were sent to Brown.[94]

The first volume was published with great difficulty owing to the limited resources of the Government. It was distributed in the name of His Highness the Maharaja. Copies were forwarded to the Marquis of Salisbury, the Secretary of State for India and to the Royal Asiatic Societies of Calcutta, Bombay, Madras and Ceylon, to the Observatories of Madras, Bombay and the Meteorological Office, Calcutta, the Geographical Society, Bombay and to the Trivandrum Public Library or Museum Library and to the Royal Society of London. Thirty copies for His Highness are being forwarded from Edinburgh addressed to the care of Arbuthnot and

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93 J. A. Brown, *op. cit.*, p. 8.
94 *Report on the Administration of Travancore for the year 1874-75*, p. 50.

Company, Madras. Arbuthnot was instructed to insert the names consisting of the persons or institutions to which the copies are to be presented.[95]

In the year 1873, Neil and Company asked the Diwan whether to proceed the contract as they stated that they have quoted very low rates for six volumes to be published and a large quantity of expensive material was procured expressly for the work for the first volume. To this the Diwan wrote to the Resident that the cost of printing the observations owes to 3,500 rupees per volume, as six volumes are proposed, the aggregate cost would be 21, 000 rupees and the sum is large relating to the resources of this country and requested the British Resident of Travancore and to the Neil Company to abandon the further publication of Brown's observations and informed the Neil Company that the author is at liberty to publish the work on his own account. In the year 1879, the Travancore Government placed the publication of the whole of the work connected with the observations at the disposal of the Royal Society of Edinburgh.[96]

Although only one volume of his work was published during his life-time, Brown's complete works were published in the Transactions of the Royal Societies of Edinburgh and London, and also in the Indian Meteorological Memoirs. In recognition of his meritorious work Brown

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95 Cover Files, 1865.
96 Ibid., 1865-79.

was awarded the Keith Prize and Medal of the Royal Society of Edinburgh for 1859- 61 and the Royal Medal of the Royal Society of London in 1878[97] in which he was awarded as the Fellow of the Royal Society of London.

Brown died in Lynton (Devonshire) on 22-11-1879. The next period of nearly two decades was one of no active work in the observatory mainly due to the absence of any Director and the reduction of the establishment. It is to be noted here that the annual charge for the establishment during the time of Brown was nearly rupees 20,000, which was reduced to rupees 1116 per year after his retirement. The routine work of meteorological observations was, however, carried on by the assistants attached to the institution.[98] The observatory then consisted of three departments, the Astronomical, the Magnetic and the Meteorological. Of these the first one the Astronomical branch was abolished in 1865 on the retirement of Brown, and the work since done at the observatory is limited to the determination of local time, the calculation of eclipses and the furnishing of other information annually required for the Almanac. The Magnetic and the Meteorological departments have however been kept up and the usual observations in each are taken and duly recorded. The magnetic

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97 *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p. 25.
98 *Ibid.*, p. 41.

observations taken in the years 1852 to 1869 had been published by Brown in the Transactions of the Royal Society in Edinburgh.[99]

The work at the observatory after the retirement of Brown was carried on by the local astronomers. With regard to the magnetical observatory, two declination magnetometers were read eight times a day-

At	6.00' -	7.30'	- 10.30'	and	11.30'	a.m.
Late	6.30' -	2.30'	- 4.30'	and	5.30'	p.m.

(2) One Adie's Horizontal Free Magnet was observed five times a day-

At	6.30' -	10.30'	and	11.30	a.m.
And at	4.30' -		and	5.30'	p.m.

The thermometer was read at 6.30' and 11.30' in the forenoon and at 5.30' in the afternoon.

(3) One Adie's Vertical Free Magnet was observed six times daily.

At	6.30' -	10.30'	and	11.30'	a.m.
And at	3.30' -	4.30'	and	5.30'	p.m.

Its thermometer was read alone with that of the Horizontal Free Magnetometer.

[99] *Report on the Administration of Travancore for the year 1880-81*, p. 85.

In the meteorological branch, the observatory had

(1) Adie's Standard Barometer was observed twice daily at 9.30' a.m. and 3.30 p.m.

(2) Newman's Standard Barometer was read four times.

At 6.30' and 9.30' a.m. and 3.30' and 5.30'p.m.

(3) The dry and wet bulb thermometer was red five times.

At 6.30' and 9.30' a.m. and at

0.30', 3.30' and 5.30' p.m.

(4) The direction and velocity of the wind and surface of the clouds was observed and recorded.

(5) The evaporation and its thermometer were read at 6.30' a.m. and 5.30'p.m.

In an official letter of October 6, 1881 by the astronomer to the acting British Resident he informed that the work of the Trivandrum Observatory can be utilized and rendered useful to science. He believed that

the observations taken there were considered to be of special value to the scientists due to the proximity of the station to the magnetic equator.[100]

Besides the usual calculations of eclipses and other phenomena for the Almanac and the daily signals of time to the Brigade for the time-gun, 75 astronomical observations were made for the determination of local time. A table of the phases of the moon and of eclipses was supplied in the year 1887-88 to the superintendent of the Church Mission Society's Press, Kottayam, for his sheet almanac.

The establishment consisted of:

	Rs
An officer in charge	50
An assistant	20
A computor	10
2 peons	13

Total = 93 a month. Formerly the observatory had an astronomer and a large establishment which cost the state over 20,000 rupees a year. But on Brown's retirement it has reduced to the above limits.[101]

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100 Cover Files, 1881, C. No. 6147, B. No. 88.
101 *Reports on the Administration of Travancore for the years 1885-86 – 1888-89*, p. 159.

Achievements of Brown

Brown's major discovery is one of the fundamental principles of terrestrial magnetism, that magnetic change or disturbance on the earth is not a local but a world-wide phenomenon. Another important discovery was his establishment of the connection between disturbances on the surface of the sun, and subsequent changes in the state of the earth's magnetism, and proving that these changes recurred after intervals of 26 or 27 days. He also reached the remarkable conclusion that large magnetic disturbances proceed from particular solar meridians. It is interesting to note that these relationships are still the subject of much research work. A third result was reached in his work on the lunar influence on terrestrial magnetism. He showed that there existed a lunar- diurnal effect; that it varied with the position of the sun, and that its amount was inversely proportional to the cube of the moon's distance. Lastly, he was the first to give a definite form to the solar-diurnal variation in terrestrial magnetic force in equatorial regions, a matter of considerable importance in the theory of the diurnal variation. These are four of the fundamental principles of the science of terrestrial magnetism as it stands today.[102]

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[102] Travancore Information and Listener, *loc. cit.*, p. 26.

CHAPTER – 5

LATER DEVELOPMENT OF ASTRONOMICAL SCIENCE IN KERALA TILL DATE

After the departure of Brown in 1869 there was a period of lull till Mitchell, Professor of Mathematics, Maharaja's College, Trivandrum offered his services to the Government as honorary director of the institution in 1892.[1] The Government gave him charge of observatory in addition to his work as Professor of Mathematics. Mitchell's main work, however, was to make the meteorological observations, for which additional instruments were purchased. There began hourly recording of meteorological data. Cloud studies were also begun during his period. He introduced a scheme of rainfall measurements in the state with a specially designed rain gauge.[2] He engaged the staff of the observatory in the compilation of a table for the reduction of observations on vapour pressures and the completion of the humidity table.[3] The observations thus collected were telegraphed to the Meteorological Department of the Government of India and were published weekly in the Government Gazette.

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1 V. Nagam Aiya, *op.cit.*, Vol. 1, New Delhi, 1989, pp. 488-489.
2 *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, Trivandrum, 1937, p. 41.
3 *Travancore Administration Report*, 1893-94, Trivandrum, p. 153.

By that time, as a result of Mrs. Brown approaching the Government of India through the Royal Societies of London and Edinburgh and other scientific bodies, the former undertook to publish the observations of Brown, whose records were then with the Royal Society of Edinburgh. Eliot, meteorological reporter to the Government of India and the person who was entrusted with the work of editing these observations, visited Trivandrum in 1892 and saw some of the instruments used by the late Brown and inspected the various places where Brown had made observations. The results were published and fully analysed and prepared a permanent record of the meteorological work of Brown in this country which was published in the Indian Meteorological Memoirs.[4]

Star observations

During the directorship of Mitchell the astronomical activities were the star observations, giving time signals, etc. Some sixty one astronomical observations were made in the year 1889-90, seventy four in the year 1890-91,[5] fifty seven in the year 1891-92 and seventeen in the year 1892-93 which was smaller when compared with previous years. The reason stated was that the instrument had to be fitted with new cross wires which is an extremely tedious and delicate operation, and partly to the prolonged

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4 *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p. 41.

5 *Travancore Administration Reports*, 1889-90, p. 182, 1892-93, p. 160.

continuance of weather unsuitable for day observations of stars,[6] fifty seven in the year 1893-94, forty eight transit observations in the year 1895-96, seventy in the year 1987-98, sixty four in the year 1898-99, eighty three in the year 1899-1900, eighty three in the year 1900-1901, sixty nine in the year 1901-1902, seventy eight in the year 1902-1903, seventy five in the year 1903-1904 and seventy one in the year 1905-1906.[7] The star observations were made by means of the transit telescope for the determination of local time, in addition to the usual calculations of eclipses and other phenomena for the Almanac, the daily signals of time was conveyed to the Brigade for the time gun.[8]

Time signals

For a long time, it was the practice to fire time-guns at Trivandrum on the basis of the time given by the observatory.[9] The observatory clocks were properly regulated in the year 1892. Time signals were made to the Nayar Brigade barracks at eleven a.m. of each week day of the year and the time of noon day gun-fire was noted on 360 days. Mitchell reported that there has been little improvement in the way in which the time guns were fired. The time was found correct only on twenty five occasions and the

6 *Ibid.*, 1892-93, p. 160.
7 *Ibid.*, 1896-97, p. 167, 1898-99, p. 152, 1899-1900, p.116, 1901-1902, p. 68, 1903-04, p. 57, 1904-05, p. 63, 1906-07, p. 66.
8 *Ibid.*, 1889-1890, p. 182.
9 *Souvenir of the Centenary of His Highness the Maharaja's Observatory,* p. 42.

average error for that period was fifteen seconds against seventeen in the year 1892.[10]

The time of gun fire was observed thrice daily on each day through out the year 1893-94. The midday gun was fired correctly on fifteen occasions, and the average error for the remaining 350 days was 11 seconds against 15 in 1893. Mitchell doubted that the errors are due to the fact the flag signal from the observatory roof was not easily seen from the Brigade compound owing to the growth of some casuarina trees at the entrance to the body Guard stables, which obstructed the view of the observatory roof from the Brigade Barracks. The system of signaling was primitive, and Mitchell had sent an estimate of the cost of a scheme for having the time gun at the Brigade fired by an electric arrangement worked from the observatory.[11]

He addressed the Government to take necessary steps for the execution of the works in connection with the fitting up of the time gun firing apparatus. The Government issued orders to the Pani Nagay Department, which entrusted the contract to Mahomed Moosa of the Marahmut Department for the erection of the line of wire from the observatory to the Brigade for the purpose of firing the time gun. The

10 Travancore Administration Report, 1892-93, p. 160.
11 *Ibid.*, 1893-94 A.D., p. 153.

terminal apparatus was fixed in April 1898 and the work of completing the line of wire was entrusted to the Public Works Department. But they did not perform their duty promptly which made Mitchell to undertake the work himself and was completed by him in June 1898. The noon day gun was correctly fired on 148 occasions in the year 1898-99, 133 of which it was fired by the electric apparatus. The error on the remaining occasions was on an average 2.8 seconds after the correct time.[12]

Thus he introduced the system of firing time guns by an electrical switch operated form the clock room of the observatory. Though this formed an improvement upon the till then existing system of daily correcting the clock kept at the Brigade indicating gun-fire times, its successful work could not be relied upon always as in the year 1899-1900, it failed to operate 134 times, including morning, noon and evening guns.[13] The error varied from a few seconds to five minutes.[14] The electric apparatus for firing the time guns was continued till it was replaced by time signal records from Colombo which was obtained from the wireless set. These recorded times were also checked with those derived from star observations by means of the transit circle or telescope.[15]

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12 *Ibid.*, (1898-99), p. 116.
13 *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p. 42.
14 *Travancore Administration Report*, 1899-1900, p. 116.
15 *Ibid.*, 1935-1936 (Part II- vol. 1), p. 1.

Extension of the astronomical building

Two telescopes were purchased in the year 1892-1893 and a very good equatorial mounting for them was obtained from Messrs Negretti and Zambra of London. Alterations and additions to the observatory building at an estimated cost of Rupees 3,400 have been sanctioned for the purpose of providing a suitable place for putting up these telescopes.[16] The astronomical building was extended to the western side and a tower of about fifty feet height was erected with a revolving dome to house a small equatorially mounted telescope of four inches aperture.[17]

Mitchell did not stay at the observatory building as done by his predecessors, as it is known that the astronomer's work is mainly at night either for the purpose of his own observations or for the purpose of showing celestial objects to visitors or students. For both these it is necessary that the astronomer should have his quarters very near the place where the instruments are housed. This would besides making him available at all hours of the evening when visitors naturally come to see the sky, allow him facility for continued observations at clear nights and for photographing stars and nebulae, which also form part of his work. Instead of staying nearer to the observatory, he stayed at Government quarters which might be

16 *Ibid.*, 1068 M.E. (1892-93), p. 160.
17 *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p. 41.

one of the reasons that he was not able to bestow as much attention to the astronomical working of the institution as he could otherwise have done. [18]

Reforms of Mitchell in the field of education

Mitchell entered into the service of His Highness Darbar in May 1890, as Professor of Pure and Applied Mathematics in the Maharajas College, Trivandrum and he became the Principal of the college in 1893. While serving in the college, he served also as the educational secretary to the Darbar for a period of over seven years from 1894 to 1902. He was appointed the first director of Public Instruction in Travancore in January 1909, and he has served in that capacity for three years.

Mitchell gained and retained the confidence of the successive Diwans who held charge of the administration of the state during the period of his service in it. He organized the chair for physics and fitted up the physics laboratory, which was recognized as one of the best equipped laboratories in southern India. As principal of the college, he contributed materially in bringing it to the high rank it occupied among the colleges affiliated to the University of Madras.

He contributed more as educational secretary to the Darbar and as director of Public Instruction than as professor or as principal. It was he

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[18] Confidential file (1904-1956), 1930, File No. 299, B. No., 1154.

who introduced, when educational secretary to the Darbar, the first set of codified rules for the organization and management of schools generally and for the grant of aid to private schools. And as director, it fell to him to frame the revised education code and to carry through many salutary reforms in the administration of the department such as the introduction of free elementary education, the establishment of the training college and normal schools for elementary teachers, the institution of the school leaving certificates, the passing of the education code, the introduction of manual training and the revision on a liberal scale of the salaries of teachers of secondary schools. These are the measures of reform which have laid the foundation of further educational progress on broad and generous lines.

The progress made by the state in the matter of education during fifteen years bear ample testimony to the wisdom of the measures adopted by the Darbar on Mitchell's advice. His whole hearted devotion to his work, his remarkable grasp of details, and the firmness he always displayed in dealing with difficult situations and in confronting the opposition inevitable when far reaching changes in the administration of a large department are initiated and carried out, all these things have gone far to place the education department on the excellent footing it occupied.

Retirement of A.C. Mitchell

Mitchell held the office of the honorary director till 1910. On January 10, 1912, a meeting of the students and friends of Crichton Mitchell was held in the college hall at five p.m. to concert measures for commemorating the services rendered by him to the cause of education in Travancore. A committee was formed by them known as the Mitchell Memorial Committee and they brought forward a souvenir on the retirement of Mitchell from the Government services.

On 21 February 1912, the principal of the Maharajas College accepted an offer from the secretaries of the Mitchell Memorial Committee to present an oil painting of Mitchell to be put up in the college hall. The Maharaja made a contribution of Rupees 500 to the Mitchell Memorial Fund. His service to the cause of education is worth mentioning as he brought many reforms in this field.[19]

He was succeeded by Stephenson, Professor of Physics. He continued the routine work started by Mitchell till 1916, when he went to England on furlough. During his time, Government appointed in 1915, Rama Varma Raja as assistant director. He was an enthusiastic amateur in astronomy and was in charge of the observatory when Stephenson was on

19 General Section, File No. 29, 1912, B. No. 88.

leave.[20] He published in 1916 an *astronomical ephemeris for 1917* adapted to the meridian of Trivandrum,[21] giving some of the important celestial information usually given in the Nautical Almanac published in England. It has to be mentioned that during the time of Caldecott, the first astronomer of Trivandrum, there were three such publications. Raja's Ephemeris was published for three more years. He also put in working condition the five inch equatorial telescope kept unused for many years before his time. As there was not sufficient funds available to house it properly it had to be erected in open space, with a small movable roofing to prevent direct sunlight and rain falling on it.[22]

The import of costly telescopes and clocks lagged behind due to financial difficulties and also due to the customs duty to import an item like a large clock or telescope roused from fifty percent to twenty five percent. It was due to these facts that Parameswaran, the Director of Technology, Madras started to construct instruments. In the year 1918, a home made eight inch reflecting telescope was put up in front of the old thatched building of the Trivandrum Observatory by Parameswaran. It was the largest telescope and that of a Swadeshi made in India.[23] The telescope was

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20 *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p. 42.
21 *Travancore Administration Report*, August 1916-August 1917, p. 87.
22 *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p. 42.
23 *Ibid.*, pp. 15-16.

thus put up at the observatory with great enthusiasm as its first reflector by Rohini Thirunal, the astronomer in charge of the observatory.[24]

In the year 1919, on the recommendation of the honorary director, the assistant director's place was abolished. In 1920 Ramanathan, lecturer in the physics department was appointed honorary director when Stephenson went on leave and he held the post till the end of 1921, when he went on leave and Sivarama Krishna Iyer, was appointed acting director of the observatory. Ramanathan took the trouble of arranging for the normals of a large number of meteorological elements being computed up to date.[25] On the night of the 29 November 1922 a cyclonic storm crossed South Travancore accompanied by very heavy rainfall and strong wind.[26] He wrote a paper on thunderstorm activity in Trivandrum and addressed the meteorological department of the Government of India in regard to the need for recognizing the meteorological work done in this institution.

Ramanathan left Travancore service in 1922 and Sivarama Krishna Iyer was confirmed as honorary director. Self recording instruments for the automatic registration of pressure, temperature, humidity and wind velocity were fitted up in 1922, and the institution was recognized as a first class meteorological observatory by the India Meteorological Department from

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24 *Ibid.*, p. 10
25 *Ibid.*, pp. 42-43.
26 *Travancore Administration Report*, 1921-22, p. 115.

1922 onwards. The results of the daily observations were published in the monthly weather review and in the annual review of the India Meteorological Department.

Appointment of Subramania Iyer as Government astronomer

In 1927, certain changes were introduced by the Government in the working of the observatory department. Government considered it necessary to revive the astronomical activity of the institution.[27]

It was proposed to appoint a Government astronomer in the observatory on an allowance of rupees 41⅔ a month or rupees 500 a year and to designate the director Sivarama Krishna Iyer as Government meteorologist, on his then allowance and instructions were given from the chief secretary to Government to the account officer, Trivandrum to make necessary provision in part I of the observatory budget for the year 1928.

The necessary additional provision was made in the Budget for 1928 and was voted by the council.[28] The observations made at the observatory were purely meteorological then. The director of the institution Sivarama Krishna Iyer who was the then Assistant Professor of Physics in the H.H. the Maharaja's College of Science was qualified to do the work and he was paid an honorarium of rupees 500 per annum.

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27 *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p. 43.
28 General Section, File No. 1359, R.O.C. No. 6 of 1927/GA.

The observations made then with regard to the astronomical department are the determination of the local time and the computation of the English Almanac. Consistent with the standard of scientific education imparted in the science college in the mathematics and physics branches, it was found essential that more than the execution of the routine work, some original investigation was to be conducted and new methods of observation were to be devised so that the institution may keep pace with the march of scientific progress and might be of practical use for students prosecuting post graduate scientific studies.[29] Subramania Iyer was found then to be qualified for the post of a Government astronomer.

Qualifications of Subramania Iyer

Subramania Iyer served as acting professor of mathematics in the H.H. the Maharajas College of Science, is a Ph.D. in astronomy of the London University and has had working experience in the astronomical institutions at Greenwich, in the London University Observatory and Radcliff Observatory, Oxford and the Solar Physics Observatory, Cambridge. He has also visited and studied the working of the observatories in Paris, Mendon (France), Potsdam and Berlin. The Government found that the experience and training of Subramania Iyer can be utilized to the fullest extent in improving and developing the observatory.

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[29] Ibid., File No.1359, R.O.C. No. 3870 of 1927/G.A.

Appointment

On 8 September 1927, Her Highness the Maharani Regent sanctioned the appointment of Subramania Iyer, acting professor of mathematics in the H.H. the Maharajas College of Science as the Government astronomer[30] and he took charge of his duties on 17 September 1927.[31]

The items of work on the astronomical side carried on during these years were:

(1) The standardisation of local time by star observations with the transit circle.

(2) The calculation of astronomical data for the Government almanac and directory and

(3) Helping visitors at star-gazing with the help of the equatorial telescope.

Of these items, one alone can be reckoned as daily routine work.

The meteorological department has been carrying out the following items of work:

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30 Ibid., File No. 1359, R.O.C. No. 3072/1927.
31 Ibid., File No. 1359, R.O.C. No. 329/1927.

(1) Observations of the meteorological elements with about fifteen different instruments and six periods daily from 6 a.m. to 8 p.m. and at other hours day and night during suspicious weather.

(2) Sending weather telegrams based on the above data to Simla, Bombay and Madras at 8 a.m. daily and at other hours whenever called for.

(3) Collection and correlation of meteorological data in several registers and arranging for their publication by the India Meteorological Department.

(4) Observations of cloud movements with Nephoscope, and preparation of upper air movement data there from for the Agra upper air Observatory.

(5) Receiving monthly rainfall statements from seventy five departmental stations and sixteen non-departmental ones and preparing rainfall statistics there for publication in the Government gazette and by the Madras Board of Revenue Department.

(6) Arranging for the supply of rain gauges and other accessories to the departmental stations.

(7) Arranging and scrutinizing the annual inspection reports on the condition of the rain gauges and responsibility for their proper up-keep.

(8) Preparation of rainfall statistics and other meteorological data for the Government almanac and directory.

(9) Preparation of meteorological data for weekly publication in the gazette and weekly rainfall returns to important officers in the capital.

(10) Up keep of several self-recording meteorological instruments yielding results of scientific interest.[32]

Bifurcation of the meteorological and astronomical branches

The establishment of the institution consisted of one head assistant, three assistants, one computor and three peons, besides a boy peon and a gardener. The head assistant supervised the whole work of the institution and one of the four subordinates attended to the correspondence.[33]

On 27 February 1928, the meteorological and astronomical branches of the observatory were made independent of each other and were placed

32 Ibid., File No. 1359, R. O.C. No. 319/1927/ G.A. dated 14-9-27.
33 Ibid., File No. 1359, R.O.C. No. 3870/27/G.A.

under the respective control of the Government meteorologist and the Government astronomer. The establishment such as the traveling allowance and contingent allotments of the department were distributed between them. The head assistant, the correspondence clerk, one peon and the gardener being allowed to the astronomical department and the rest of the staff to remain with the Government meteorologist, the correspondence clerk of the astronomical department attended to the correspondence of the meteorological department also.[34]

Distribution of traveling allowance and contingencies are as follows:

Traveling allowance

There was an allotment of rupees fifty in the budget. This went to the astronomer who required money for his visit to Madras and Kodaikkanal Observatories. This he was asked to find by the diversion from the amount allotted for instruments.

Contingencies- Furniture – rupees 100

The whole of the money went to the astronomical department. The meteorological department was already equipped with the necessary furniture.

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34 Ibid., File No. 1359, General, 1372/28, G.A and also in appendix 3.

Purchase of astronomical instruments

A sum of rupees 5000 was provided for the purchase of astronomical instruments. Subramania Iyer was entrusted to select and purchase the necessary and useful instruments.

Repair to instruments - rupees 100

The meteorological section has very few instruments to repair. The amount is usually allotted for repairing clocks, telescopes etc. Since however a large amount was given for the purchase of instruments the allotment for repair was asked to be divided equally between the two departments.

Rain gauges

For rupees 200, the whole of this amount went to the meteorological department.

Pay of menials – rupees 147

The pay of the gardener for the remaining months of the year was allotted to the astronomer.

Books and periodicals-rupees 120

Three journals were got down for the astronomical side and two for the meteorological side. The cost of the latter was two dollars and two shelling which coasted rupees eighty to the astronomical section and rupees forty to the meteorological section.

Anchal charges-rupees 10 and office expenses-rupees 130

It was divided equally between the two departments.

Permanent advance

A permanent advance of rupees thirty was sanctioned to the Government astronomer.[35]

Astronomical activities

The activities in the astronomical department from its bifurcation to its transfer to the University of Travancore, under the guidance of Subramania Iyer, were analysed under various headings as instruments, time signals, observations, visitors, astronomer's visit, training of students and the financial aspect.

35 General Section, 1928, File No. 349, B. No. 234 and also in appendix 4.

Instruments

A sum of rupees 5000 was provided by the Government for the purchase of astronomical instruments and in the year 1928-29, a portable three inch equatorially mounted telescope and an astro camera were purchased and was added to the stock of instruments in the institution.[36]

In the year 1929, the Government was under consideration of constructing new buildings for housing the astronomical and meteorological instruments and to make certain alterations in the existing buildings on the observatory hill at a cost of rupees 21,500 in view of the location of the reservoir connected with the water supply scheme on the hill[37] and in 1931 the observatory buildings built by Brown and Mitchell had to be dismantled, as that spot had to be given over to the engineering department for the construction of a high level reservoir for distributing water in various parts of the town for the Willingdon water works.[38] There was no other site so high and fitted for the purpose, and various other sites were inspected for locating the new observatory. None could be found as good as the observatory hill; thereupon Government sanctioned the construction of a new building adjacent to the high level reservoir, for locating the

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36 *Travancore Administration Report*, 1104 M.E. (1928-1929), pp. 257-259.
37 Confidential files, 1930, File No. 299, B. No. 1154.
38 A. Sreedhara Menon, *Gazetteer of India-Kerala*, Trivandrum, 1962, p. 614.

observatory in addition to part of the quarters of the astronomer built during the time of Brown.[39]

The new observatory building was finished and handed over to the astronomer towards the end of 1107 M.E. (1931-1932)[40] which was constructed nearer to the high level reservoir. The five inch equatorial has been shifted to the top of the newly built reservoir and is thus able to secure a better view of the sky all round, than its old position allowed then.[41] The slit in the transit room has been finished and the adjustment of the transit circle was completed in the same year.[42] These constructions and installations of the transit instrument and the equatorials and fixing of the clocks in the new rooms etc, took a long time, as the latter involved a series of observations extending over many weeks.[43]

In the year 1931-1932, the sidereal and the mean solar time clocks were transferred to the new building. They were both cleaned and regulated. The transit circle was transferred to the newly built transit room and was mounted properly. The large equatorial telescope was shifted to the terrace of the new observatory building. The wireless receiving set also has been removed to the new building.

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39 *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p. 46.
40 *Travancore Administration Report*, 1107 M.E. (1931-1932), p. 1.
41 *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p.46.
42 *Travancore Administration Report* 1107 M.E. (1931-1932), p.1.
43 *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p. 47.

All other instruments were kept in good condition then.[44] During 1932-33, a new solar chronometer was made in brass and it gave mean time directly with fair accuracy. In the year 1933-34, a new sun-dial, with the equation of time marked on a brass plate attached to it, was constructed in cement concrete in front of the observatory annex. The exact mean time could be noted from it correct to a minute.[45]

The mean solar clock, by which the gun time is controlled, had a steady rate for the major portion of the year 1934-45. Its maximum daily variation never went beyond 1.5 seconds and the clock showed the exact times for about two months from July to August in the year 1934-1935.[46]

As per the Government orders, conveyed in their letter no. R.O.C. 131/37/Army dated 13 February 1937, the clock kept at the Cantonment Barracks was removed to the observatory on 18-3-1937 and the mechanism placed in position. After necessary tests and comparison with the standard astronomical clock of the observatory, the above clock was regulated and kept good time.[47]

The import of costly telescopes and clocks lagged behind due to financial difficulties and high customs duty. It was in these circumstances

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44 *Travancore Administration Report*, 1107 M.E. (1931-32), p. 1.
45 *Ibid.*, 1933-34, p. 248.
46 *Ibid.*, 1934-35, p. 1.
47 *Ibid.*, 1936-37, p. 1.

that Parameswaran, the director of technology with the research students whom he has directed at Madras started to construct instruments. They made telescopes large as well as small, reflectors as well as refractors, ranging in size from one inch to twenty four inch aperture.

A very moderate size telescope is one of at least twelve inch in aperture and to import it would perhaps cost rupees 12,000 which he had mounted in his house at Madras at a cost of less than rupees 2000. The largest telescope in India made by an Indian the twenty four inch reflecting telescope mirror which he started upon in 1935 was a "fait accompli". Instead of the rupees 15,000 it should have cost to import, it had cost him barely rupees 3,000.[48]

The astro-camera of the observatory was taken to Madras to try with the electric clock drive at the private observatory of Parameswaran, as per Government letter no. D. Dis. 1255/36/Edn. Dated 3 September 1936. On trial it has yielded very good results and was responsible for the discovery of a Nova in Pleiades.[49]

On the occasion of the centenary meeting held on 23 December 1937, Parameswaran presented to the observatory a twelve inch reflecting

48 *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, pp.15-16.
49 *Travancore Administration Report*, 1936-37, p. 1.

mirror and its accessories, made by him.[50] The 172 years old window to the world of stars still has that four inch 'transit telescope' that was used to track the movement of a selected star for keeping tract of Indian Standard Time. Also housed here are the clocks that were used in those days for this purpose.[51]

Time signals

From 1929 daily time signals were received by the use of a wireless set. Till then, the mean time clock was standardised only by the star observations with the four inch transit circle, whose errors had not been well determined and allowed for so as to give time correct to a fraction of a second. With the introduction of time signal observations and their checking by transit observations of stars, time determination became more accurate and less dependent on transit observations, which could not be made for nearly half the year due to bad weather conditions.

Another change made in connection with giving accurate time to the public was the system of firing the time gun by the use of an electric signal controlled from the clock room of the observatory. This was different from the type started by Mitchell and discontinued later. A light signal at the gun shed given by the operation of a switch in front of the mean time clock,

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50 *Ibid.*, 1937-1938, p. 1.

51 *The Hindu*, November 4, 2005, p. 6.

gave the exact instant for firing the gun. This arrangement started in 1935, was working satisfactorily then had not failed in all those days and the time given was relied on correct to a second.[52]

The number of star observations in the year 1928-29 made with the transit circle for standardising local time and regulating errors in the fixing of the time gun was 128 against 160 in the previous year. In 1929-30 it was decreased to 106 and 103 in 1930-31. The decrease was due to bad weather conditions and also to the fact that there was an alternative method of determining local time with the help of the wireless set.[53]

There was the recording of the time signal from Colombo and Manila stations, the total number of time signals recorded in the year 1106 M.E. (1930-1931) being 131.[54] The star observations for 1107 M.E. (1931-1932 A.D.) were mainly for adjustment of the transit circle and the equatorial telescopes. For this purpose a series of continued observations of several stars had to be taken. The weather in the latter part of 1107 M.E. was rainy and cloudy and therefore these observations had to be extended for many days before the instruments could be fixed.

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52 *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, pp. 45-46.
53 *Travancore Administration Report*, 1104 M.E. (1928-29), pp. 257-259.
54 *Ibid.*, 1106 M.E. (1930-32), p. 253.

The local time was standardized during the year 1107 and 1108 M.E. (1932-33) from time signal records obtained with the radio set. Time signals from Colombo and Manila were recorded regularly. In 1107 M.E., 274 time-signals were recorded satisfactorily as against 131 in the previous year and 252 in 1932-33.[55] 1095 time guns were fired during the year 1931-1932 of which only forty four were fired in time, while 341 were too early with an average error of 14.7 seconds, and 710 were fired too late with an average error of 20.3 seconds.[56]

During the year 1109 M.E. (1933-34) the spider lines of the transit circle were replaced by a ruled glass plate obtained from London and star observations were taken mainly to verify the proper fixing of the plate in position. Two hundred and forty eight time signals from Colombo were recorded.[57] In 1110 M.E. (1934-35), 332 time signals from Colombo were recorded satisfactorily and 220 transit observations were taken to verify the errors of the clock and 355 in 1935-1936.

The errors in the times of firing of the daily time guns from 17 August 1934 to 9 March 1935 were noted as was done in the previous years. The average error in the times of firing of the time guns ranged from +12 seconds to -18 seconds. From the 10 March 1935, the time gun firing is

[55] *Ibid.*, 1107 M.E. (1931-32), p. 1.
[56] *Ibid.*, p. 2.
[57] *Ibid.*, (1933-34), p. 248.

being controlled by a light signal given from the clock room of the observatory. By this arrangement, the error in the time of gun fire is reduced to almost nothing. However, on the 30 May 1935 the evening gun was fired eighteen seconds late, owing to the missing of the cap used for firing.[58]

355 time signals from Colombo were recorded satisfactorily during 1935-36 and 345 in 1112 M.E. (1936-1937). The times for firing time guns were regulated by the light signal from the clock room of the observatory and hence all the time guns were fired in time, except on a few occasions. Consequent on the proposal to remove the Travancore artillery to Pangode, it was suggested to fire the time gun from Pangode. Accordingly Government in their letter no. R.O.C. 3416/36/Edn. Dated 12 October 1936 directed to remove one such gun to Pangode to test whether the firing from Pangode could be heard over as wide a range as the firing from the cantonment barracks. Accordingly the noon guns from 25 January 1937 to 13 February 1937 were fired from Pangode. As the firing from Pangode was not done by the light signal from the observatory, there were some errors in the times of gun fire on those days. The sound of the gun from Pangode was some what low, probably due to the resistance of the wind and to the greater distance.[59]

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58 *Ibid.*, (1934-35), p. 1.
59 *Ibid.*, (1936-37), p. 1.

353 time signals were recorded in 1937-38. A light signal at the gun shed given by the operation of a switch in front of the mean time clock, gave the exact instant for firing the gun. This arrangement which was started in 1935, was working satisfactorily then and has not failed since then to give the correct time and could be relied on correct to a second.[60]

In the days when automatic clocks had not yet been in business, calculating Indian Standard Time (IST) was a complicated business involving many observatories. In those years one such observatory that helped the nation keep time was the observatory in Thiruvananthapuram.[61]

Observations

During the year 1930-31, there was only one total lunar eclipse visible at Trivandrum.[62] In 1931-1932, there were two eclipses visible at Trivandrum, of which one was a total eclipse of the moon that occurred on the 26th and the 27th September 1931, and the other a partial eclipse of the moon, which occurred on the 22 March 1932. Both these were observed and the observed times of contact and the calculated times were compared.[63]

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60 *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p.46.
61 *The Hindu*, November 4, 2005, p. 6.
62 *Travancore Administration Report*, 1930-31, p. 253.
63 *Ibid.*, 1931-32, p. 1.

During the year (1932-1933) there was only one partial eclipse of the moon visible at Trivandrum. Seventy-eight star observations were made during the year 1932-1933 by means of the transit telescope mainly for the final adjustment of the transit circle. There were three eclipses visible at Trivandrum during the year 1933-34, of which, one was a partial solar eclipse and the other two partial eclipses of the moon. The observed times of contact, etc. and the calculated times of the eclipses were found to agree.[64]

In 1934-35 there was only one eclipse visible at Trivandrum, and this was a total eclipse of the moon, which occurred on the 19th of January 1935. On 15 March 1935, a solar Halo was observed during midday and it was photographed being a rare phenomenon.[65]

Two eclipses of the moon were visible at Trivandrum during 1935-36. One of which was a total eclipse and the other a partial one.[66] There was a partial transit of Mercury over the sun's disc on 11 May, 1937 visible at Trivandrum for a very short time[67] and the number of transits of stars observed in the year 1937-38, was 180.[68]

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64 *Ibid.*, 1933-34, p. 248.
65 *Ibid.*, 1934-35, p. 258.
66 *Ibid.*, 1935-36, p. 258.
67 *Ibid.*, 1936-37, p. 1.
68 *Ibid.*, 1937-38, p. 1.

Visitors

During the year 1928-29 and in 1929-30 several batches of students from colleges in and outside Travancore visited the observatory in order to gain practical knowledge on the use of the several astronomical instruments for the study of celestial bodies.[69] His Highness the Maharaja paid a visit to the observatory along with Dutt, Administrative Tutor, on the 2 October 1931/ 16 Kanny 1107.

The students from the local colleges were given the usual facilities for observation and practical work. A few important visitors, to the observatory during the year 1107 M.E. (1931-1932) were the students and teachers from Palamcotta, students and teachers from Nagercoil, students from the Training School for Rural Reconstruction at Marthandom, students for the Vernacular Higher Grade Examination, The Captain and other navel officers of H. M. I. S. "Hindustan" and a party of twelve students from Bishop Herber College, Trichinopoly.[70]

The mathematics students from the science college, usually visited yearly once to the observatory and they were given the usual facilities for observation and study of practical astronomy. The number of students from

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[69] *Ibid.*, 1928-29, p. 2.
[70] *Ibid.*, 1931-32, p. 2.

colleges and schools outside Travancore during the year 1937-1938 was greater when compared with those of previous years.

The list of a few of the important visitors who came to the observatory during the year 1934-1935 are a group of students and lecturers from Pasumalai, a party of students and teachers from Salem, a party of final year students of the agricultural college, Coimbatore, Chandy, civil surgeon, Bombay, Narayanan, chief inspector of mining, Mysore, a batch of students from St. John's College, Palamcotta, Colonel Garsteen, Agent to the Governor General, Madras state, a party of students from St. Xavier's College, Palamcotta,[71] Sachivottama Ramaswami Iyer, Diwan of Travancore visited the institution on 6 August 1937, the students from Trichy, Scouts and masters from flame group, Cochin state, Ramakrishna Iyer, Government Survey Training School, Tirunelvelly, Seth, Commissioner, Rajaratnam and party from Kanchipuram, Sister's from St.Roch's Training School, Vasudeva Sarma and a party from Tenkasi etc.[72] Special facilities were given for observation to the delegates and members of the All-India Oriental Conference, which took place at Trivandrum during the last week of December 1937.[73]

71 *Ibid.*, 1934-35, p. 2.
72 *Ibid.*, 1936-37, p. 1.
73 *Ibid.*, 1937-38, p. 2.

Today the observatory is the meeting place of amateur astronomers and others with an eye on the stars. At night and these star gazers make a beeline for the five inch refractor telescope that serves as the main viewing equipment here. It may be the Moon, Mars or Venus-celestial bodies many million of kilometers away appear at an arms length.

The observatory also witnesses a rush of people whenever there is a solar eclipse. This, despite the fact that people can see the moon eating into the sun only as an image reflected on to a piece of paper. Even so the fact remains that these telescopes and the three others in the observatory were purchased in the nineteenth century.[74]

Astronomer's visit

During the year 1929-30, the Government astronomer was deputed to the observatory at Kodaikkanal for a period of one month to familiarize himself with the working of that institution and to study the working of the various instruments there.[75]

The Government astronomer was deputed to attend the Indian Science Congress held at Nagpur in the first week of January 1931. He was also deputed to visit the Nizamiah Observatory at Hyderabad to acquaint

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74 *The Hindu*, November 4, 2005, p.6.
75 *Travancore Administration Report*, 1929-30, p. 263.

himself with the astrographic and other stellar photographic works done there.[76]

The Government deputed him again in the year 1931-32 to the Kodaikkanal Observatory for a stay of about a week in June 1932 to familiarize himself with the solar work that was being done there. During his stay there a few photographs of the sun in the calcium and hydrogen lines were taken and studied and also a solar prominence was observed through the prominence spectroscope and was studied.[77]

Training of students

Apart from giving all facilities to the students of the science colleges in both studying the sky and the use of the chief astronomical instruments, training of students in practical and observational astronomy has been undertaken and it is gratifying to note that this is perhaps the only astronomical institution in India where such instructions were given to students who came seeking it. No fee has been charged for such instructions though this involved additional work for the staff. Some students who offered astronomy as one of their subjects of study for the I.C.S. examination had undergone training in this observatory since 1932.[78]

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[76] *Ibid.*, 1930-31, p. 253.
[77] *Ibid.*, 1931-32, p.3.
[78] *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p. 46.

Venkataraman, B.A. from Madras and Koshy, M.A. from Alwaye college, the candidates for the I.C.S. examination, were given the necessary training in practical astronomy as per general sanction conveyed in Government letter R. Dis. 866/32/Edn., dated 8 August 1932.[79]

Financial aspect

It is to be noted that the annual charge for the establishment during the time of Brown was nearly rupees 20,000 which was reduced to rupees 1116 per year after his retirement. Again it increased to rupees 16,408.35 in 1920-21. This increase was mainly due to the purchase of new instruments in the meteorological department. Self recording instruments for the automatic registration of pressure, temperature, humidity and wind velocity were fitted up in 1922, and the institution was recognized as a first class meteorological observatory by the Indian Meteorological Department from 1922 onwards.

The financial aspects of the observatory never increased above 10,000 after 1921-22 until the observatory came under the control of the University of Kerala in 1939. In 1951, the astronomical section came under the control of the state Government. The financial aspect continued to be the same as in 1939 till 1960-61, when the administrative control of the

[79] *Travancore Administration Report*, 1937-38, p. 2.

observatory was transferred to the Revenue Board, Trivandrum and the observatory was ordered to function as an independent department under the charge of an honorary director. After 1960, the expenses of the observatory increased to rupees 15,537 in 1963-64 and to rupees 16,408.35 in 1968-69 and went on increasing after 1970 as the activities of the observatory increased.

Malayalam calendar computing section

Weekly publications of astronomical notes on local mean time of rising, setting and meridian passage of the sun, moon and all the planets and on their respective positions in the sky at local mean noon were made in advance in the Government Gazette.[80]

Towards the end of 1934 Government asked Subramania Iyer to be in charge of the Malayalam almanac computing section, which was till then housed in the Huzur secretariat buildings. It was thought convenient to remove the office of this section temporarily to the observatory buildings[81] and the staff for the purpose, which was attached to the Government secretariat, was transferred to the observatory.[82] Three issues of the almanac were published under the supervision of the astronomer.

80 *Travancore Administration Report*, 1927-28, p. 215.
81 *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, p. 47.
82 *Travancore Administration Report*, 1934-35, p. 257.

The main work of this section is the computation of the Malayalam *Panchangom* according to the Hindu traditional method. The first Government Malayalam *Panchangom* was published about the year 1837 A.D., so that it was entering into its 100^{th} year of working under the patronage of His Highness the Maharaja.

The facilities given for the almanac computing section to work with those employed in computations according to modern astronomical methods are bound to improve the accuracy of the Hindu mode of calculating the positions of celestial bodies, which has a past history of several centuries. The astronomical calculations devised by the ancient Hindus, though they do not yield the same accurate results as modern astronomical calculations, are in themselves tolerably interesting and have a value in as much as they form the basis of many religious and other festivals regulating the lives of many Hindus all over India.

When it is also remembered that all their knowledge and calculations are based upon continuous and patient observations with the naked eye and other simple instruments, it is even now a matter of great wonder how even such an amount of accuracy has been possible. Therefore when this mode of calculation received the improvement that is possible by the introduction of western astronomy where ever necessary, we can expect a result for which there was so much of demand then.

It was thought necessary then to compare the Malayalam calendar computation with the results of computation embodied in any western calendar, and at the same time it was allowed to preserve its special features wherever possible.[83] During the latter part of the year (1936-37) Government decided to revise the Travancore Almanac and Directory from 1938 in accordance with the Government letter R.O.C. no. 641/37 ACC, Dated 2 April 1937.[84]

Transfer of the observatory to the control of the University

In 1937, the centenary year of the observatory, the University of Travancore was established and incorporated under the Travancore University Act I of 1113 (1937-38) which was issued as Royal Proclamation by His Highness Sri Chithira Tirunal Balarama Varma, Maharaja of Travancore, on the occasion of his 26th birthday on November 1, 1937 with the Maharaja as its Chancellor.[85]

Early in Chingam 1114 (1938-39), Government transferred the following quasi-educational institutions to the control of the University.

(i) The Trivandrum Public Library

(ii) His Highness the Maharaja's School of Arts

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[83] *Souvenir of the Centenary of His Highness the Maharaja's Observatory*, pp. 47-48.
[84] *Travancore Administration Report*, 1936-37, p. 1.
[85] A. Sreedhara Menon, *History of the University of Kerala*, Vol. 1, Thiruvananthapuram, 2003, p. 38.

(iii) The Trivandrum Observatory (including the astronomical and meteorological sections).[86]

On August 17, 1939 the observatory was transferred to the control of the University and it functioned as a unit of the Central Institute of Research.[87] Under the auspices of the University the following public lectures were delivered during the year, 1938-39 by Subramania Iyer, a retired Head Master on "Ancient Astronomy" (six lectures) and Moudgill, Principal, College of Science and Subramania Iyer, Professor of Mathematics in the college were deputed to attend the Indian Science Congress at Lahore in January 1939.[88] In the year 1940 the meteorological and astronomical sections were amalgamated. The observatory attended primarily to the work of astronomical observation, calendar computation and daily collection of data on rainfall.

The Trivandrum Observatory captured the attention of the scientific world when the new comet (1941-C) was sighted at the observatory on the morning of 23 January, 1941 by Subramania Iyer.[89] It was sighted with the five inch refractor telescope situated on the major water tank.[90] The fact was communicated by cablegram to the Astronomer Royal in England. It

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86 *Travancore Administration Report*, 1114 M.E. (1938-39), p. 200.
87 A. Sreedhara Menon, History of the University of Kerala, *op. cit.*, p. 495.
88 *Travancore Administration Report*, 1938-39, p.200.
89 A. Sreedhara Menon, History of the University of Kerala, *op. cit.*, p. 38.
90 Miscellaneous records available in the Trivandrum Observatory.

later came to light that the same comet was sighted also from other observatories outside India. Nevertheless, the discovery in the Trivandrum Observatory was an independent one and hence it was hailed as a significant achievement. The comet was kept under constant observation with the five inch telescope of the observatory for almost a month and the findings were subsequently intimated to Greenwich.[91]

The other instruments at the observatory are a 3.5 inch refractor telescope which is used after sunset. The four inch transit refractor is used to adjust the time by viewing the position of the Polaris star or on the passage of stars across the meridian, the eleven inch telescope was used for the discoveries and in weather forecasting. The Sidereal Clock is a special clock which is based upon "star time" and the Sundial is an instrument for telling time by the sun. It indicates the time of day by the shadow, cast on a surface marked to show hours or fractions of hours, of an object on which the sun's ray's fall. It was in 1941 that Vikram Sarabhai had his Cosmic ray experiment at this observatory.[92]

A preliminary orbit of the comet was also computed by Kuttan Nair (then assistant in the observatory) from the first observations recorded at the observatory. The results so obtained were corroborated by the ephemeris

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91 A. Sreedhara Menon, History of the University of Kerala, *op.cit.*, p. 496.
92 Miscellaneous records available in the Trivandrum Observatory.

published from other observatories as well.[93] In 1951, a part of the items of work in the meteorological section was taken under the control of the India Meteorological Department. What remained under the state observatory are the astronomical section and a part of the meteorological work relating to the rainfall registration. These two items of work continued as usual.

From January 18, 1960 the administrative control of the observatory was transferred to the Revenue Board, Trivandrum and the observatory was ordered to function as an independent department under the charge of an Honorary Director. From 1960 to 1975, several transit observations were made with the transit instrument for standardizing the local sidereal time. Information regarding exact time was furnished to Government Departments and private persons whenever called for.[94]

Visitor's that included teachers and students from various colleges and schools in the state and parties on educational tours from outside Kerala visited the observatory seeking facilities for astronomical observations and to gain knowledge in the working of the astronomical instruments. They were given necessary facilities.[95]

There was the feeling that the development of the observatory was not getting proper attention and even its modest facilities were being under

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93 A. Sreedhara Menon, History of the University of Kerala, *op.cit.*
94 *Kerala State Administrative Report*, 1960-61, Trivandrum, 1962, p. 49.
95 *Ibid.*, 1963-64, p. 140.

utilized. The Trivandrum Science Society comprised of students of the city colleges took the initiative in focusing the attention of the Government and the public on this aspect. On January 1, 1976 the Government of Kerala decided to transfer the observatory back to the control of the University. The observatory functions as an institution under the Department of Physics, University of Kerala. The Head of the Department became the Director of the observatory. It was hoped then that this step would help the observatory as a centre of study and research.

The period 1986-1987 represents an active phase in the working of the observatory. The world wide enthusiasm over the arrival of Halley's Comet, the transit of the planet Mercury across the solar disc on November 13, 1986 and the total lunar eclipse of October 17, 1986 came as a blessing in disguise and gave a boost to the activities of the observatory. To facilitate observations in this regard, the Kerala State Science, Technology and Environment Committee sanctioned a scheme entitled 'Augmentation of Telescope Accessories with Prabhakaran Nair, Reader-in-Charge of the observatory, as the principal investigator. Under this scheme, the existing telescopes of the observatory were repaired and a new drive system and a photographic attachment to the telescopes were built.

Under the Halley's Comet watch programme, Prabhakaran Nair took active role in the scheme 'Ten Thousand Astronomy Classes" sponsored by

the Central Department of Science and Technology and conducted by the Kerala Sastra Sahitya Parishad. During this period the observatory also arranged slide shows, talks and sky-watch programmes for the astronomy lovers of Trivandrum. These programmes are still going on at the observatory. It may be noted in this context that Halley's Comet was first sighted in this region through the 5 inch telescope of the observatory both during its pre perihelion time during November 1985 and during the post-perihelion time in February 1986. (Perihelion is that point in a comet's orbit at which it is nearest to the sun). During this period the observatory worked almost on all night's and nearly 10,000 people visited it. Similarly, the transit of Mercury was sighted through the five inch telescope of the observatory and was transmitted by the Trivandrum Doordarshan Kendra.[96]

In fact, since its take-over by the University, the observatory has been functioning as a centre of education in astronomy. Students from all parts of the state and the neighboring districts have been coming to have a gaze at the stars, planets, moon and other celestial objects through the five inch telescope. In order to popularize the science, several radio talks were given by Professor Viswanathan, Head of the University Department of Physics in the year 1987 and Prabhakaran Nair on topics of general interest to students of astronomy. In collaboration with the Kerala Sastra Sahitya

[96] A. Sreedhara Menon, History of the University of Kerala, *op.cit.*, p. 497.

Parishad and the Kerala Astronomy Association, the observatory has also been conducting classes in astronomy for high-school and college students. The hundred and fiftieth anniversary of the founding of the Trivandrum Observatory and the golden jubilee of the University of Kerala fell in the same year i.e. 1987. The event was celebrated in a fitting manner at a colourful function held at the observatory hill on July 14, 1987 with the Vice-Chancellor, Habeeb Mohamed, presiding Chandrasekharan, Minister for Education, Government of Kerala, formally inaugurated the function then. As part of the celebrations, the Department of Physics, University of Kerala organized a series of lectures called Allan Brown Memorial Lectures. The first lecture in the series was delivered by Professor Yeshpal, Chairman of the University Grants Commission at the Kerala University Senate Chamber on July 16, 1987.[97]

There are scientific and technological institutions like VSSC (Vikram Sarabhai Space Centre) at Veli, near Thumba, Thiruvananthapuram. It was in 1962 that the Indian National Committee on Space Research (INCOSPAR) was formed by the Department of Atomic Energy with Dr. Vikram Sarabhai as chairman to organize a national space programme. Vikram Sarabhai Space Centre has its origin in the Thumba Equatorial Rocket Launching Station (TERLS). TERLS became operational on

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[97] *Ibid.*

November 21, 1963 with the successful launching of the first sounding rocket, 'Nike Apache'. The VSSC is the lead centre for launch vehicle development in India. It pioneers in rocket research and launch vehicle projects of Indian Space Research Organisation (ISRO) under the Department of Space (DOS), Government of India. VSSC is named after Dr. Vikram A Sarabhai, the founding father of Indian Space Programme.

The main objective of space programme includes development of satellites launch vehicles sounding rockets and associated ground systems. The experimental phase included Satellite Instructional Television Experiment (SITE), Satellite Telecommunication Experiment (STEP), remote sensing application projects, and satellites like Aryabhata, Bhaskara, Rohini, APPLE and launch vehicles, SLV -3 (India's first Satellite Launch Vehicle) and ASLV(Augmented Satellite Launch Vehicle). The present operational space systems include Indian National Satellite (INSAT) for tele – communication, television, broad casting, meteorology and disaster warning and Indian Remote Sensing Satellite (IRS) for resources monitoring and management. The Polar Satellite Launch Vehicle (PSLV) used for launching IRS satellites and Geo – Synchronous Satellite Launch Vehicle (GSLV), intended for launching INSAT class of satellites. The space science activities include SROSS and IRS – P3 satellites, participation in international science campaigns and ground systems like

MST (Mesosphere – Stratosphere – Troposphere) Radar. The ISRO's co – operative arrangements cover several countries and space agencies. The ISRO provides training in space field to personnel from other countries. The ISRO's hardware and services available commercially through Antrix Corporation.

The development of Rohini sounding rockets has not only helped the Indian scientists conduct high altitude experiments but also played a significant role in the realization of India's own satellite launch vehicle SLV – 3. Over the years VSSC has designed, developed and launched a family of these rockets under the generic name, Rohini Sounding Rockets (RSR) to serve a range of scientific missions. They are used for carrying out research in areas like meteorology and upper atmospheric processes up to an altitude of about 500 km.[98]

The other organizations are the Madhava Observatory which is also known as the Calicut University Observatory, the first of its kind in any University in the state was opened on August 7, 2005. Naresh Dadhich, astronomer and director of Inter – University Centre for Astronomy and Astrophysics (IUCAA) Pune, inaugurated the observatory which is named after Madhava, the great astronomer. A 14 – inch MEADE (Cassegrain) telescope connected to a CCD, through which accurate stellar photometry

98 Miscellaneous records available in the ISRO library, Thiruvananthapuram.

will be possible, is the main attraction. The telescope is fixed to an isolation pier so as to prevent external vibration. In addition, the observatory also has an 18" NGT telescope gifted by IIAP (Indian Institute of Astro Physics), Bangalore.[99]

The Astronomy club at the Mar Thoma College, Tiruvalla, was started in the college with the aim to cultivate research interest among the students in the field of astronomy and astrophysics. The club uses a 150 mm astronomical telescope for observations. The telescope was constructed at Inter University Centre for Astronomy and Astrophysics (IUCAA), Pune by the trainee students of the Mar Thoma College.[100]

C.V. Raman Centre for Basic Astronomy was opened at Trivandrum on October 2008. It plans to teach the students to make small telescopes and also the basics of using one for star gazing. A big attraction is that students will get to gaze through the new 11 – inch, GPS (Global Positioning System) – facilitated celestron telescope acquired by the museum.[101]

The Priyadarshini Planetarium is situated within the Kerala State Science and Technology Museum premises in Thiruvananthapuram. The planetarium organizes various science related shows, which deals with the

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99 www.universityofcalicut.info/campus/observatorycnt.htm
100 www.marthomacollege.org/aboutus/co_curricular.htm
101 *The Hindu*, October 27, 2008.

origin and different stages of development of astronomy, the structure of different planets and the origin of the universe.[102]

Kollam is getting ready to have a full – fledged observatory with international standards, in the International Year of Astronomy (2009). It will be set up at the initiative of the All Kerala Astro Science Society (AKAS). Former Vice – Chancellor of Kozhikode University and renowned astrophysics teacher Sasidharan, is the founder president of the AKAS. It is planning to take space observation to the villages by using a mobile telescope. Opposition leader Oommen Chandy inaugurated the activities of the AKAS at the Asramam Government open air auditorium on March 7, 2009. ISRO chairman Madhavan Nair inaugurated the programme 'space observation to the villages' at the function presided over by Mayor Padmalochanan.[103]

Astronomical events from 2002 to 2009

The astronomical events during the year 2002-2003 had given much coverage for the observatory in the media such as the arrival of Ikeya-Zhang Comet (2002) and other astronomical events like eclipses, occultations and transits have contributed in reviving the activities of the

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102 www.tvmonnet.com/html/priyadarshini_planetarium.htm

103 *The Hindu*, March 08, 2009 and also in *Express News Service*, March 06, 2009.

observatory.[104] The rare alignment of Jupiter, Saturn, Venus, Mars, Mercury and Moon in the sky (2002),[105] transit of the planet Mercury across the solar disc (2003),[106] historic Mars opposition (2003) and on June 8, 2004 Venus glided across (transit) the face of the sun for the first time since 1882 taking a little more than six hours to complete its journey. The entire Venus transit was visible from India. The Kerala University observatory participated in the International observational group in this context.[107] These activities had given a boost to the observatory. A partial solar eclipse was visible on October 3, 2005. Professor Vaidyan, the director explained the *Hindu* that "The five degree tilt in the orbit of the moon ensures that we see only two eclipses in a year. Otherwise there would have been an eclipse each month. The elliptical orbit of the moon around the sun ensures that not all eclipses are total".[108] An annular solar eclipse was visible on September 22, 2006; a partial lunar eclipse on September 7, 2006, a partial solar eclipse was seen on March 19, 2007. Two central solar and two lunar eclipses was visible at Trivandrum during 2008. There had been an occultation of Mars and Moon on May 10, 2008 visible at Trivandrum. The year 2009 will witness two solar eclipses and four lunar eclipses. The two solar are the annular solar eclipse on January 26, 2009 and the total solar eclipse on July 22, 2009 and

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104 Miscellaneous records available in the Trivandrum Observatory.
105 *Deepika*, May 11, 2002, Trivandrum, p. 1. and also in *Malayala Manorama*, May 12, 2002, p. 3.
106 *Deshabhimani*, August 15, 2003, Trivandrum, p. 12.
107 *The Hindu*, June 9, 2004, p. 2.
108 *The Hindu*, October 3, 2005, p. 3 and also in *Mathrubhumi*, October 4, 2005, p. 1.

the lunar eclipses are penumbral lunar eclipse on February 09, July 07, 2009 and on August 06, 2009. There will be a partial lunar eclipse on December 31, 2009.

On December 1, 2008, the occurrence of the crescent moon and the two planets (which takes twelve years to rotate around the sun) left many with enough astronomical questions to ponder. Star gazers in the city were wonder-struck at an unusual configuration in the sky.[109]

Seminars and Conferences organized in the recent past by the observatory

A five day workshop on astronomical image processing in collaboration with IUCAA, Pune on December 1996, a one day workshop in Telescope making and Sky watching in collaboration with C-DIT, Kerala on February 2001, XXII Annual Conference of the Astronomical Society of India on February 2003, a seminar on Mars Expedition on August 2003, projection of live images to screen on December 2005, a ten days summer course for selected thirty students during April/May 2005 and on August 15, 2008 an astronomical exhibition was conducted by the observatory.

[109] *The Hindu*, December 2, 2008, p. 2 and also in *Mathrubhumi*, December 2, 2008, p. 1.

Research and Science Popularization activities

University has decided to upgrade the activities of the observatory both in research and popularization of astronomy and is now equipped with good computational facility, library and audio-video facilities. It is now possible for few M.Phil/M.Sc. students to do their project work with these facilities. Recently, the observatory was modernized with the introduction of 11'' telescope, SUN work stations and image processing software. The astronomy programmes of the observatory have been carried out jointly with the Inter University Centre for Astronomy and Astrophysics (IUCAA), Pune. The observatory has been supplying observation details about various astronomical events like Venus transit, planetary alignment, arrival of comets etc. to the public through media. The reputed mosques in Kerala acknowledge the availability of timings of sunrise, sunset, moonrise and moonset, etc. Daily sky watching programme starts at 6.30 p.m. on every working day. The general public is allowed to enjoy sky watching provided the sky is clear. There is a visiting pass of rupees five for adults and rupees three for children. With the present modern facilities like eleven inch telescope, CCD camera, sun workstations, image processing facility and collaboration with national programmes, the observatory will grow as one of the important centers in astronomy and related fields in our country.

Future Plans

The year 2009 will be celebrated as the Astronomical year and the University has sanctioned fifteen lakhs of rupees to the observatory. The observatory has a plan for the procurement of a Dobsonian type eight inch reflector telescope and for a procurement of a fully computerized small radio telescope for daily solar observation.

The observatory that was once directly under the king of Travancore is now a subsidiary institution of the Department of Physics of the University of Kerala. This is the meeting place of amateur astronomers and others with an eye on the stars. At night these star gazers make a bee line for the five inch refractor telescope that serves as the main viewing equipment here. It may be the Moon, Mars or Venus-Celestial bodies' many millions of kilometers away appear at an arms length. The observatory also witnesses a rush of people whenever there is a solar eclipse. This, despite the fact that people can see the Moon eating into the Sun only as an image reflected on to a piece of paper.[110]

110 Miscellaneous records available in the Trivandrum Observatory.

CONCLUSION

The history of astronomy in Kerala is a hitherto unexplored area. Among the scientific inventions and institutions, Kerala, the God's own country commands a pre – eminent status. But the historians and scholars pay little attention to unravel such secrets. Astronomy is one such area where the land of Kerala especially the princely state of Travancore made certain everlasting contribution. Kerala had made substantial contributions in the field of traditional Hindu astronomy both observational and computational starting from the fourth century A.D. Indeed the achievements of some eminent astronomers of Kerala such as Vararuci, Sankaranārāyana, Talakkulathu Govinda Bhattatiri, Sangamagrāma Mādhava, Parameswaran of Vatasseri, Nilakantha Somayaji etc., have been particularly remarkable as is evinced by their numerous contributions to astronomy and astrology.

Astronomical Science in Kerala assumed greater significance during the ancient period when a well equipped observatory or planetarium was established at Mahodayapuram under the charge of Sankaranārāyana in 849 A.D. It functioned in accordance with the principles laid down by Aryābhatta. For about three centuries after Sankaranārāyana, Kerala does

not seem to have produced any outstanding astronomer or mathematician. The scholars of the period were perhaps content with the preservation and transmission of the knowledge from generation to generation. But it was a period of active progress in the field in North India. Bhāskara II wrote in A. D. 1170 the *Siddhanta Śiromani,* a comprehensive work in four parts, namely Lilavati, Bijaganita, Grahaganita and Gola, which became popular through out India. Such works gave new impetus to the studies in Kerala, and from the thirteenth century onwards there has been an unbroken tradition for about five hundred years. The members of the Kerala School were predominantly (Namboothiri) Brahmins with a few who came from other castes, such as the Variyars and the Pisharatis, traditionally associated with specific duties in the temple. The short distance between the *illoms* and the temple brought these people to have a close interaction with the namboothiris and to learn astronomy from them.

During eighteenth, nineteenth and twentieth centuries, the British tried to utilise astronomical science for their commercial interest and political ambition. The promotion of the knowledge of astronomy, geography and navigation in India enabled them to know the latitude and longitude of India and thereby to expand their territories. The foundation of modern science in India was laid by the Europeans. They introduced the scientific knowledge of the west and brought contemporary science to

India. This changed the situation in India and led to an intellectual awakening particularly from the nineteenth century. The British rule in particular marked the beginning of a scientific revival in India. At first the individuals were responsible for scientific studies and later the East India Company encouraged the growth of science and technology by setting up scientific institutions. While the former promoted science for the expansion of scientific knowledge, the latter did it for commercial reasons. For this purpose they began to construct observatories in different parts of the country.

The observatory at Trivandrum, which owed its origin chiefly to the interest taken in the matter by the late Raja of Travancore, His Highness Swathi Thirunal Rama Varma (1829 – 47) was established in 1836, on a hill nearly 195 feet above the sea level, the first astronomer being John Caldecott. The reason for an observatory at Trivandrum was that the institution was intended to give an impetus to science by taking advantage of the fact that the magnetic equator, the line on which the magnetic needle dips neither to north nor to south passes through the state and that the Maharaja desired that his country should partake with European nations in scientific investigation. The best and most extensive observations in Travancore however, were made by John Allan Brown, who became astronomer to the princely state of Travancore in January 1852, by whom in

1855 a branch observatory was established on the peak of Agastia, 6200 feet above the sea. He made some major discoveries in terrestrial magnetism.

After the departure of Brown in 1869 there was a period of lull till Mitchell became the honorary director of the institution in 1892. Mitchell's main work was confined to meteorological observations, for which additional instruments were purchased by him. During his time He introduced a scheme of rainfall measurements in the state with a specially designed rain gauge. The astronomical observations were limited to the standardization of local time by star observations with the transit circle, the calculation of astronomical data for the Government almanac and directory and in helping visitors at star gazing with the help of the equatorial telescope. It was found essential that more than the execution of the routine work, some original investigation was to be conducted and new methods of observation were to be devised so that the institution may keep pace with the march of scientific progress and might be of practical use for the students.

From 1910 to 1922 the observatory functioned under Stephenson, Professor of Physics till 1916, when he went to England on furlough. During his time, Government appointed in 1915, Rama Varma Raja as assistant director. He was an enthusiastic amateur in astronomy and was in

charge of the observatory when Stephenson was on leave. He published in 1916 an *astronomical ephemeris for 1917* adapted to the meridian of Trivandrum, giving some of the important celestial information usually given in the Nautical Almanac published in England. He also put in working condition the 5 inch equatorial telescope kept unused for many years before his time. As there was not sufficient funds available to house it properly it had to be erected in open space, with a small movable roofing to prevent direct sunlight and rain falling on it.

The import of costly telescopes and clocks lagged behind due to financial difficulties and also due to the customs duty to import an item like a large clock or telescope roused from 50 percent to 25 percent. It was due to these facts that Parameswaran, the Director of Technology, Madras started to construct instruments. In the year 1918, a home made 8 inch reflecting telescope was put up in front of the old thatched building of the Trivandrum Observatory by Parameswaran. It was the largest telescope and that of a Swadeshi made in India. The telescope was thus put up at the observatory with great enthusiasm as its first reflector by Rohini Thirunal, the astronomer in charge of the observatory.

In the year 1919, on the recommendation of the honorary director, the assistant director's place was abolished. In 1920 Ramanathan, lecturer in the physics department was appointed honorary director when

Stephenson went on leave and he held the post till the end of 1921, when he went on leave and Sivarama Krishna Iyer, was appointed acting director of the observatory. Ramanathan left Travancore service in 1922 and Sivarama Krishna Iyer was confirmed as honorary director. Self recording instruments for the automatic registration of pressure, temperature, humidity and wind velocity were fitted up in 1922, and the institution was recognized as a first class meteorological observatory by the India Meteorological Department from 1922 onwards. The results of the daily observations were published in the monthly weather review and in the annual review of the India Meteorological Department.

On 27 February 1928, the meteorological and the astronomical branches of the observatory were made independent of each other and were placed under the respective control of the Government meteorologist and the Government astronomer. Sivarama Krishna Iyer became the Government meteorologist and Subramania Iyer was appointed as the Government astronomer. It was during the period of Subramania Iyer that the instruments constructed under the guidance of Parameswaran, the director of technology with the research students whom he has directed at Madras were bought by the Trivandrum Observatory. This improved the financial position of the observatory as it regulated the import of costly

telescopes from England. The astro – camera of the observatory was responsible for the discovery of a Nova in Pleiades.

From 1929 daily time signals were received by the use of a wireless set. Till then, the mean time clock was standardized only by the star observations with the four inch transit circle. The time determination became more accurate and less dependent on transit observations, which could not be made for nearly half the year due to bad weather conditions. Another change made in connection with giving accurate time to the public was the system of firing the time gun by the use of an electric signal controlled from the clock room of the observatory. This arrangement started in 1935, was working satisfactorily then had not failed in those days and the time given was relied on correct to a second.

On August 17, 1939 the observatory was transferred to the control of the University and it functioned as a unit of the central Institute of Research. In the year 1940 the meteorological and the astronomical sections were amalgamated. The observatory attended primarily to the work of astronomical observations, calendar computation and daily collection of data on rainfall. The Trivandrum Observatory captured the attention of the scientific world when the new comet (1941 – C) was sighted at the observatory on the morning of 23 January, 1941 by Subramania Iyer. In 1951, a part of the items of work in the meteorological section was taken

under the control of the India Meteorological Department. What remained under the state observatory are the astronomical section and a part of the meteorological work relating to the rainfall registration.

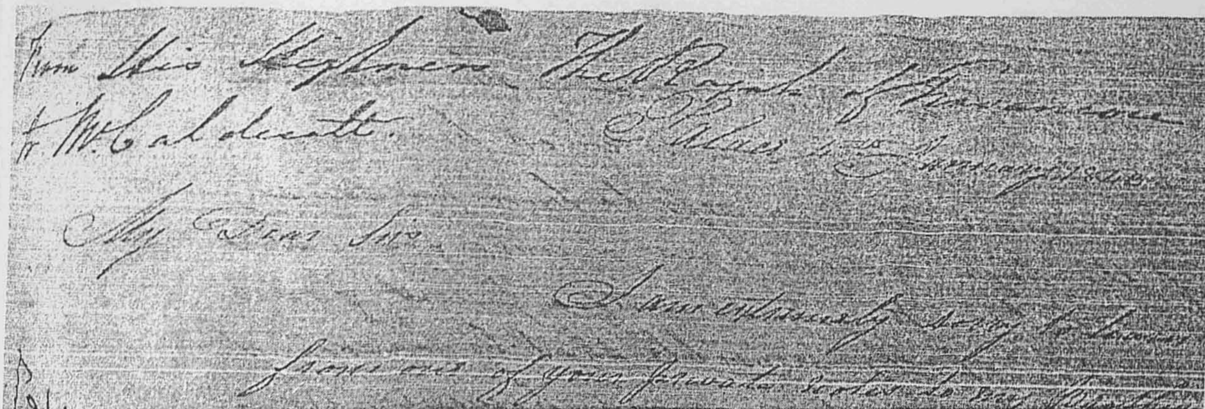
From January 18, 1960 the administrative control of the observatory was transferred to the Revenue Board, Trivandrum and the observatory was ordered to function as an independent department under the charge of an Honorary Director. As there was a feeling that the development of the observatory was not getting proper attention and even its modest facilities were being under utilized, the Government of Kerala decided to transfer the observatory back to the control of the University. On January 1, 1976 the observatory was handed over to the Department of Physics, University of Kerala. The Head of the Department become the Director of the observatory. From then on there were numerous activities such as conducting astronomy classes, seminars, conferences, radio talks, exhibitions etc. The observatory has been functioning as a centre of education in astronomy. Students from all parts of the state and the neighboring districts of Tamilnadu are coming in large numbers to have a gaze at the stars, planets, moon and other celestial objects through the five inch telescope.

There are scientific and technological institutions like VSSC (Vikram Sarabhai Space Centre) at Veli, near Thumba, Thiruvananthapuram, established

in 1962, the Madhava Observatory which is also known as the Calicut University Observatory, was opened on August 7, 2005. C.V. Raman Centre for Basic Astronomy was opened at Trivandrum on October 2008. The Priyadarshini Planetarium situated within the Kerala State Science and Technology Museum premises in Thiruvananthapuram and a full – fledged observatory is getting ready at Kollam which is to be inaugurated during the International Year of Astronomy 2009.

Astronomical investigations, a natural corollary to man's inquisitiveness and efforts to unravel the secrets of natural phenomena are as old as human civilization itself. Kerala kept the torch burning bright in this field and has contributed much to the growth and development of astronomical studies.

APPENDIX - 1


From His Highness The Rajah of Travancore
To Mr Caldecott.
Palace 4th January 1840
My Dear Sir,
I am extremely sorry to learn
from one of your private notes to my brother

From His Highness The Rajah of Travancore — *Palace, 4th January 1840*
To Mr Caldecott

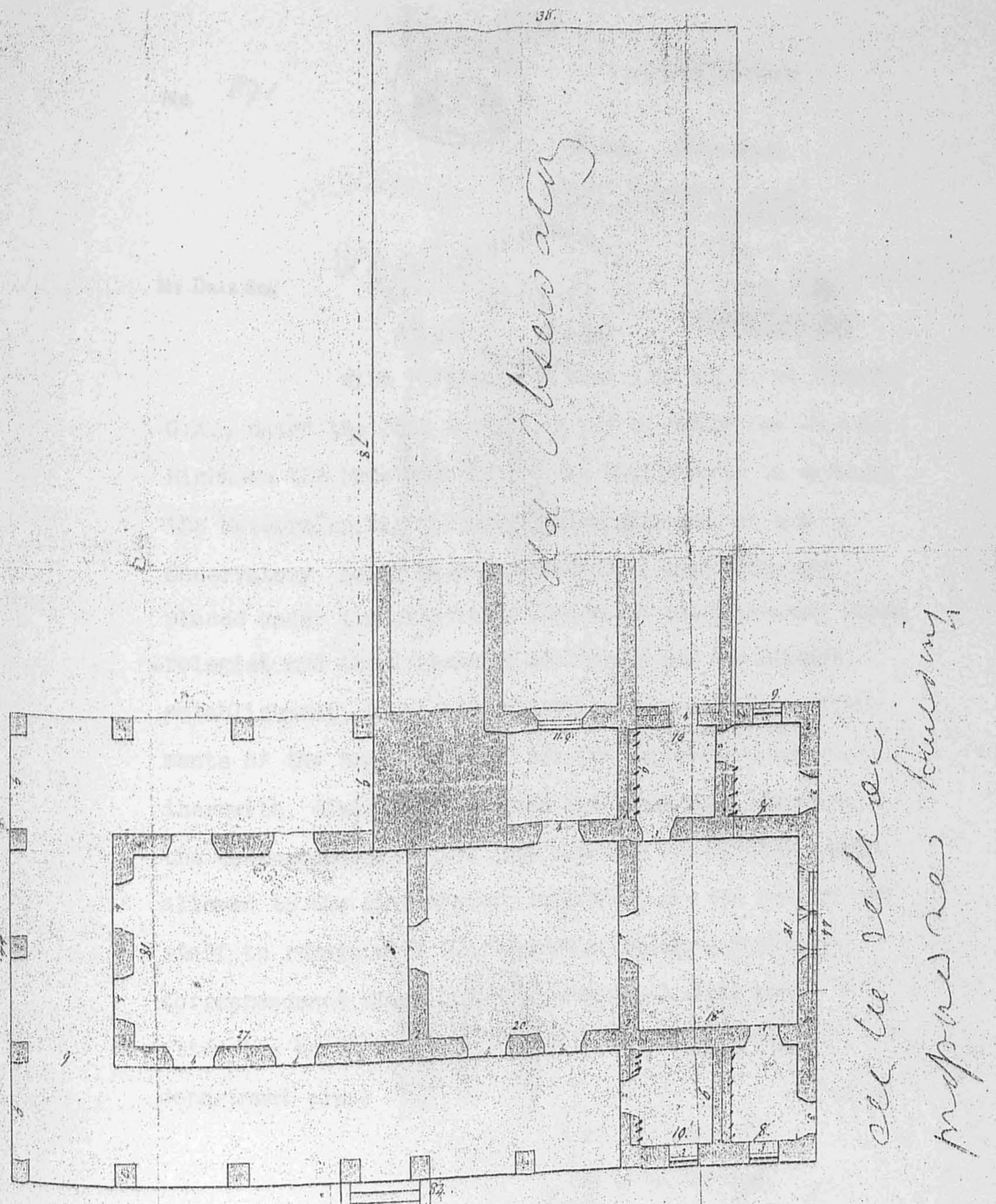
My Dear Sir,
I am extremely sorry to learn from one of your private notes to my brother that you received an intimation from the resident to the effect that I frequently evinced to him much regret at the expenses incurred on account of the observatory establishment and that in consequence I am inclined to abolish that institution altogether, adding <likewise ?> that you made up your mind to </> to resign your situation, if the Resident's communication on the subject be not unfounded. Hence I must not omit to say, in diametrical opposition to what the Resident has been pleased to intimate to you <?> my sentiments that neither such mean idea has ever entered into my head, nor have I, either directly or indirectly communicated anything upon this point to the above purport, but on the contrary, whenever Kristna Rao, who, you know, is a vulgar minded man and a total stranger to any learning at all, endeavored to persuade that there no utility by the continuation of the observatory establishment, I used to check him and at the same time express to him my sense of the high advantage derived from this establishment in a scientific point of view, as I am fully sensible that by reason of my patronizing it, my name, however, undeserving if any celebrity is favorably noticed even in distant regions, among the scientific personages of the present day.

I hope that from the above statement, you will fully understand my sincere wish to continue the observatory permanently and as I am always resolved to assist and promote the establishment as far as it lies in my power. I request you will cast off any suspicions upon this score which I am afraid are purposely excited to create misunderstanding between us and firmly rely upon my foregoing assurances.
I remain,
Yours very faithfully

J Caldecott, Esq, FRS

From the Archives of Royal Society London, Purchased by Dr Achuthsankar S Nair

APPENDIX - 2



JOHN ALLAN BROWN'S PLAN OF THE PROPOSED NEW BUILDING

Covey Files, 1853, C. NO. 16101

APPENDIX - 3

GOVERNMENT OF TRAVANCORE

Palace Form No. 81.
G. P. T. 1298. 1,000. 25-5-1102.

No. 871

Palace, Trivandrum,

27th February 1928.

DEWAN OF

HUZUR CUTCHERRY
25 FEB 1928
TRIVANDRUM

GENL. A.
1372

7465

My Dear Sir,

With reference to your D.O. R.O.C. No.3870/27/ G.A., dated the 20th instant, I beg to inform you that Her Highness the Maha Rani Regent has been pleased to sanction the Meteorological and Astronomical Branches of the Observatory being made independent of each other and placed under the respective control of the Government Meteo-rologist and the Government Astronomer, and the present establishment, Travelling Allowance and contingent allot-ments of the Department, as per the statement forwarded therewith, distributed between them, the Head Assistant, the correspondence clerk, one peon and the gardener being allowed to the Astronomical department and the rest of the staff to remain with the Government Meteorologist, the correspondence clerk of the Astronomical department attending to the correspondence of the Meteorological department also.

I am, My dear Sir,

Yours faithfully,

M. E. Watts Esquire B.A., Bar-at-Law,

Dewan of Travancore.

APPENDIX - 4

5

Proposed distribution.

Present allotments.	Astronomical Department.	Meteorological Department
1. T.A. Rs.50.	Rs. 50.	Nil.
2. Purchase and repair of furniture Rs.100.	Rs. 100.	Nil.
3. Purchase of astronomical instruments Rs. 5,000.	Rs. 5,000.	Nil.
4. Repairs to instruments Rs.100.	Rs. 50.	Rs.50.
5. Supply of rain gauges Rs.200.	Nil.	Rs.200.
6. Pay of menials Rs.147.	Rs. 42. (The pay of the gardener for the remaining 6 months of the year.)	Rs.105. (Balance.)
7. Purchase of books etc. Rs.120.	Rs. 80.	Rs.40.
8. Charts and minor instruments Rs.500.	nil	Rs 500.
9. Anchal charges Rs.10.	Rs. 5.	Rs. 5.
10. Office expenses and miscellaneous Rs.130	The unexpended balance to be divided equally between the two departments.	

GLOSSARY

Angulas	-	Measurement
Apakrama-mandala	-	Ecliptic
Atri	-	Among the seven eternal sages in the sky
Bhāsya	-	Interpretation
Caturmasya	-	Four months from July to October
Darbar	-	Court
Ghatika-mandala	-	Celestial equator
Graha	-	Planet
Grahana-lekhana	-	Graphical representation of eclipses
Grahanavidhi	-	Computation of eclipses
Illom	-	The usual name for a namboothiri's house
Ketu	-	Moon's south (descending) node
Kuttakara	-	Linear indeterminate equations
Mandala	-	A chapter of a Veda
Nakshatras	-	Stars

Rahu - Ascending lunar node

Rishi - Sage

Rtus - Seasons

Samvatsara - Full year

Sarkar - Government

Srngonnati - Phases of the moon

Svarbhanu - *Surya* is obscured by an *Asura* called Svarbhanu

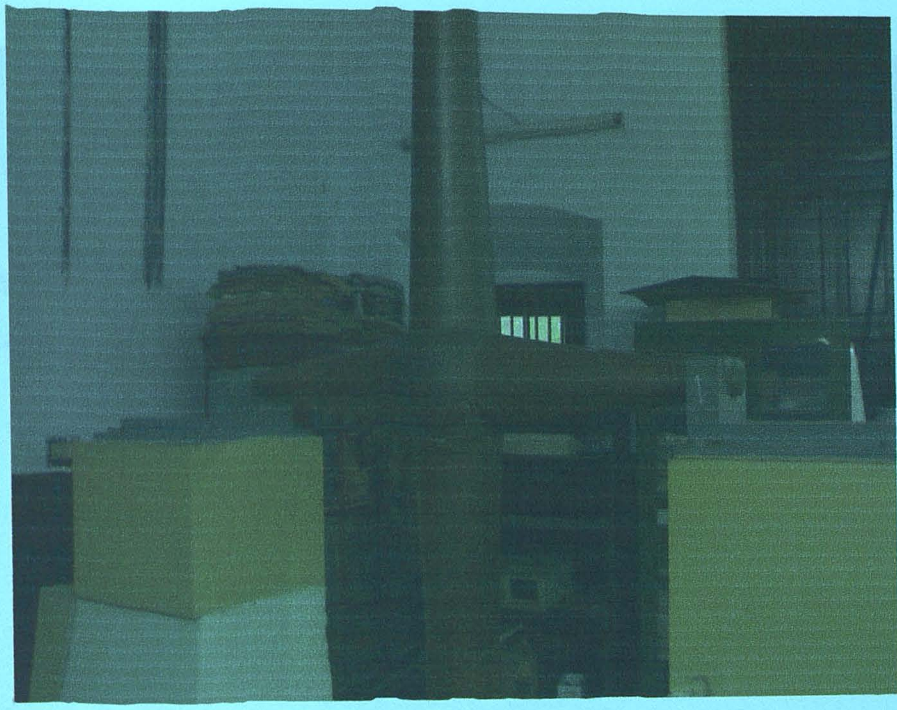
Tithi - A lunar day

Visuvant - Summer solstice

Yogana - A vedic measure of distance

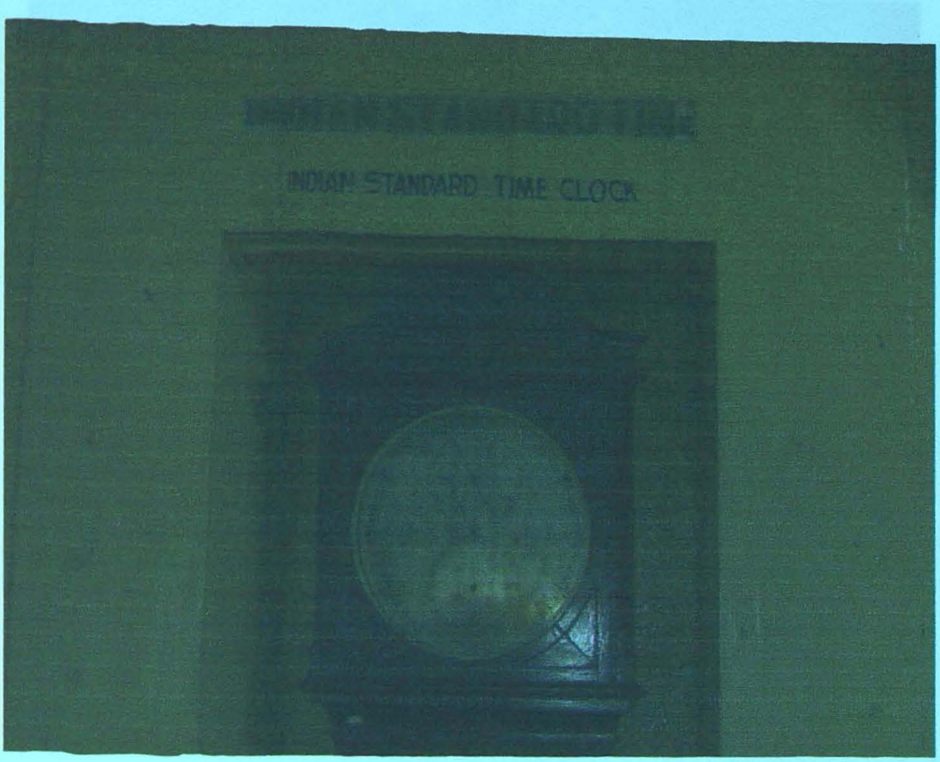
PLATES

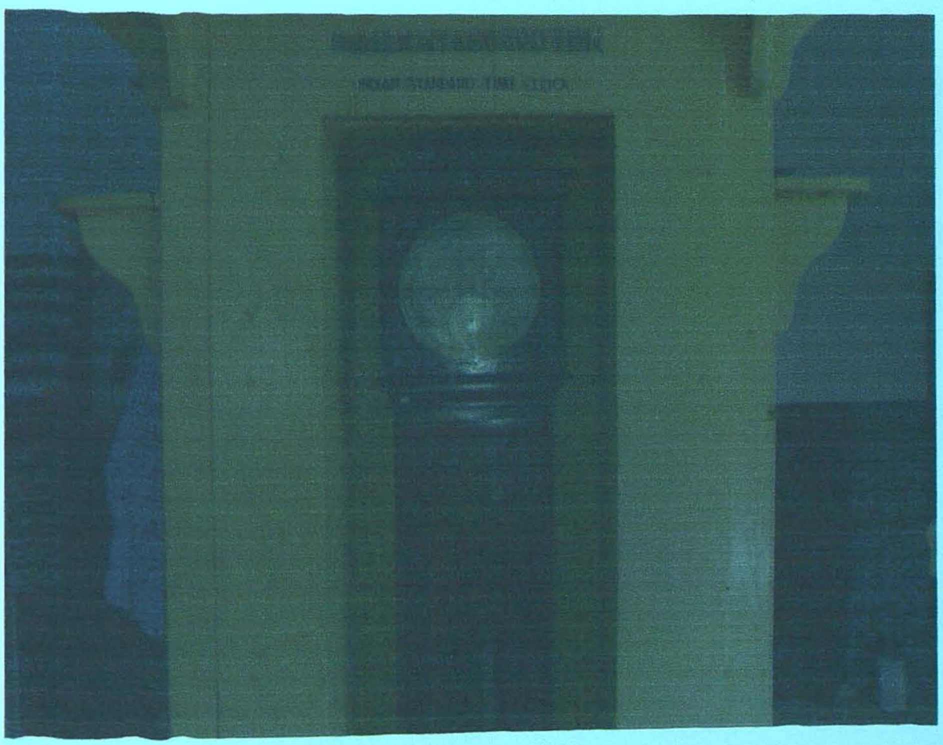
Astronomical Observatory



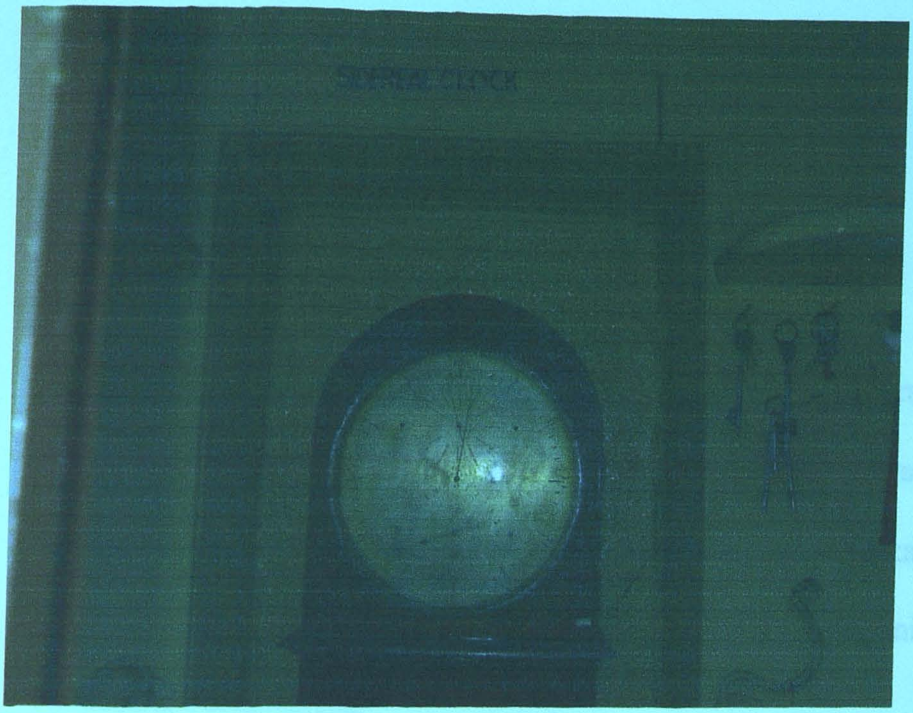
Transit Telescope

2 ½ inch Refractive Telescope

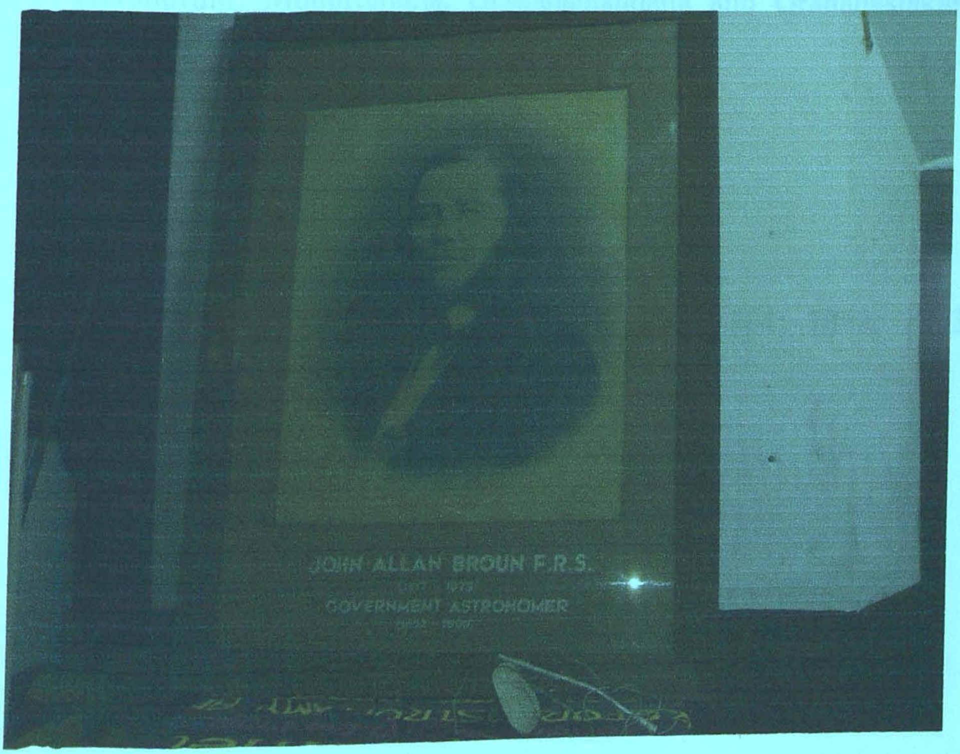




Indian Standard Time Clock



Sidereal Clock



John Allan Broun

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